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ARTS AND SCIENCES.

TACTICS, MILITARY (τακτικός), properly signifies the art of forming the troops of an army in order of battle, and of making changes in the dispositions of the troops according as circumstances may require: that is to say, the science which guides the formations when the armies come into presence of one another; while, on the other hand, STRATEGY is that division of the science of war which considers all previous operations and combinations. These two subjects will therefore be considered together under the article WAR, SCIENCE OF.

TACTICS, NAVAL. This branch of the art of war is in some respects similar to that by which the operations of armies on land are regulated; and it is desirable that the order preserved in sailing should resemble that used in moving the battalions of an army on shore. But at sea the motive power is not always to be depended on, and many a well-arranged plan of attack becomes useless from the failure of wind, change of wind, or other causes. There are, however, accepted fundamental rules by which the navies of European nations are guided in the disposition of a fleet for attack, defence, chase, or retreat; and we first notice those applicable to sailing-ships principally.

The ancients, previously to the commencement of a naval action, drew up the ships in each fleet abreast of each other, and in that order one of the fleets moved on, or waited for the attack; for each ship being propelled by oars, and armed with a beak of iron or brass projecting before the bows, efforts were generally made to direct it so as by an oblique impulse to destroy the oars on one side of a ship of the enemy, and thus render it unmanageable, or so as with the beak to pierce a side, and thus sink the ship; and hence, in the ancient manœuvres, each commander always endeavoured to keep the prow of his ship presented to the ship which was opposed to him. But since the employment of gunpowder in naval warfare, each ship in two hostile fleets is manœuvred so as to bring one of its sides to bear against the bows or against a side of its opponent, in order that it may have the power of pouring into the latter the greatest quantity of fire; and since it is the object of both commanders to avoid being raked, a general action can take place only when the hostile fleets are drawn up in two lines parallel to each other, the keels of the ships in each being in the direction of the line. In the treatise of Père l'Hoste on naval evolutions, this mode of engaging is said to have been first employed at the battle of the Texel (1665), when James II., then duke of York, commanded the English fleet. Paul l'Hoste, who was a professor of mathematics at Toulon, and died at a comparatively early age in 1700, had personal experience in many of the battles he describes, and his remarks continue to be quoted; therefore he may be fairly considered to be the founder of the present system of naval tactics.

The order of sailing for a fleet should obviously be such that the several ships may be as near together as possible, both for the sake of mutual support and that the signals which may be made by the admiral may be distinctly seen: it depends also necessarily on the order of battle, since it is of importance that the fleet should be enabled, with the utmost facility, to pass from either of these states to the other.

Writers on naval tactics distinguish five different orders of sailing, the wind continuing to blow in one direction, and the keels of the ships remaining constantly parallel to one another; in other words, all the ships steering the same course. The first order is that in which all the ships are abreast of each other in a line perpendicular to the direction of the wind; and the second is that in which the ships are arranged so that a line joining all their main-masts is oblique to that direction; but in this order the line may have two different positions with respect to the wind, for each ship may be on the starboard (the right hand) side, or on the port (left hand) side of that which is to leeward of it. As in either of these two dispositions each ship in the line has that which is next to it on one side, opposite to one of its bows, and that which is next to it on the other side, opposite one of its quarters, this order of sailing is frequently called the *bow and quarter* line. In the first and second orders, if the ships are numerous, the line is inconveniently extended.

The third order of sailing is that in which, all the sails being *close-hauled*, the ships are formed in two lines making with each other an angle of about 12 *points*, or 135°; the admiral's ship being in the centre.

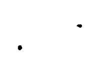


Fig. 1.

N.B. By the expression close-hauled is to be understood such a disposition of the sails that the ship may advance as nearly as possible towards the part of the horizon from whence the wind blows. In general, the line of direction of the wind makes then, on the side next to the ship's head, an angle of about 6 *points*, or 67° 30′.

The fourth order is that in which the ships, steering with the wind on one and the same quarter, are formed in several lines, divisions, or squadrons, and as much concentrated as possible. The ships of the commanders are ahead of the several divisions, and a line joining the mainmasts of all the ships in each is supposed to be in the direction of the wind. This order is very convenient for a convoy, but it presents great difficulties to the formation of the line of battle. In the fifth order, the fleet, if not very numerous, is divided into three squadrons the ships of which sail in as many parallel lines: if numerous, each squadron may be divided into two or more parts, so that the whole

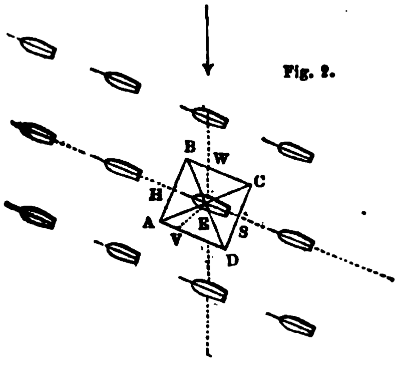


Fig. 2.

may constitute six or nine parallel lines, the number of ships being equal in all. The ships in this order are supposed to be close-hauled, and the keel of each ship coincides with the direction of the line to which it belongs, or the ships of each line sail in each other's wake; while the corresponding ships in the different divisions may be either abreast of each other or in bow-and-quarter position. A line drawn through the mainmasts of the corresponding ships in the different divisions may be supposed to coincide with the direction of the wind. This order of sailing is that which was considered the most advantageous on account of the facility which it afforded for forming the line of battle. Generally, the fleet consisting of three divisions, the vanguard of the line constitutes the weather division, and is commanded by the vice-admiral; the centre division is commanded by the admiral himself; and the leeward or rear-division, by the rear-admiral. If the fleet consists of more than three divisions, those which are not commanded by the admirals are under the direction of commodores, or senior-captains, and each commander is in the centre of his own line; frigates, store-ships, &c. are kept to windward of the line of battle-ships.

The first and second orders of sailing are easily formed, however irregular may be the previous dispositions of the ships; for the ship which is appointed to lead in the formation may get to leeward of the whole fleet, and then hauling her wind (disposing her sails so that she may move in a line making the given inclination to the direction of the wind), she may sail in the proposed direction: the other ships then, according to their positions, follow successively in her wake, and when all are proceeding in one line, each veers [Veering] or bears away, steering in the prescribed course, and still preserving the general line. The third order of sailing is formed after all the ships have got into one line, steering in each other's wake as above mentioned, and the line making an angle of about 10 *points*, 112° 30′, with the direction of the wind (reckoning from the latter direction towards the bows of the ship). The van ships, which are those to leeward of the admiral, who is supposed to be in the centre, successively haul their wind and steer in the proposed direction; and when the admiral's ship has hauled her wind, the sternmost or windward ships do the same, and each proceeds in a direction parallel to that of the other ships. The fourth and fifth orders of sailing are formed by the leading ships of the different divisions getting abreast of each other, or in bow-and-quarter position, at the prescribed distances; and then the ships of the respective squadrons taking their places in each other's wakes.

In the orders of sailing, the distance of one ship from another, in line, should be such that any danger of running foul of each other may be avoided: in general, that distance may be considered as equal to two or three cables' length (each = 120 fathoms). And, with respect to the distances between the several lines in the fifth order of sailing, it has been determined, the ships being close-hauled, by supposing that a line joining the headmost ship of one of the leeward divisions, and the sternmost ship of the next division to windward, should be at right angles to the direction of the wind; or that the angle which such line makes with each division should be equal to 2 *points*, or 22° 30′. In general, this interval may be considered as equal to six or nine cables' length; and it is of importance that the distances prescribed by the admiral of the fleet should be strictly preserved.

In order that the commander of any one ship may readily ascertain and preserve his relative position in a fleet when in order of sailing, the ingenious device called the *naval square*, which was invented by Père l'Hoste, may be employed. It consists in tracing upon the quarter-deck a great square ABCD (diagrams Nos. 2 and 3), having two sides, AD and BC, parallel to the ship's length; the diagonals, AC and BD, intersecting each other in E, and the line HES being drawn vertically over the ship's keel; also the point H being towards the head of the ship. Now, if a ship were sailing in the direction SH, close-hauled on the starboard tack, as in the cut No. 2, so that BD coincides with the plane of the sail, and WE (bisecting the angle HEC) with the direction in which the wind is blowing; then, after having tacked and become close-hauled upon the port tack, since the directions of the vertical planes passing through the keel and sail make angles with the direction of the wind equal to those which they made before tacking, the line SH, that is, the line on which the ship will be sailing, will coincide with, or be parallel to, the position of EC in the diagram. In like manner, if a ship be sailing in the direction SH, close-hauled on the port tack, so that AC coincides with the plane of the sail, and VE with the direction in which the wind is blowing; then, after having tacked and become close-hauled on the starboard tack, the line SH, on which the ship will be sailing, will coincide with, or be parallel to, the position of ED in the diagram.

Hence, if a fleet be in three parallel divisions, the ships sailing abreast of each other, those in each line will be in the direction SH, and the corresponding ships in the different divisions will be in the directions AB or DC. If the fleet sails close-hauled, and, for example, on a starboard tack as in No. 2, the ships in each line will be in a direction coincident with or parallel to SH, and the corresponding ships in the several lines will be in a direction coincident with, or parallel to, WE, which is that of the wind. Again, if the fleet is in three divisions, and the ships are sailing in parallel directions not coinciding with those of the divisions; if, for example, the ships should be sailing on the port line of bearing while close-hauled on the starboard tack, as in the subjoined diagram, the ships in each line will be in the direction of one of the diagonals of the square; and the corresponding ships in the different divisions will be in that of the other.

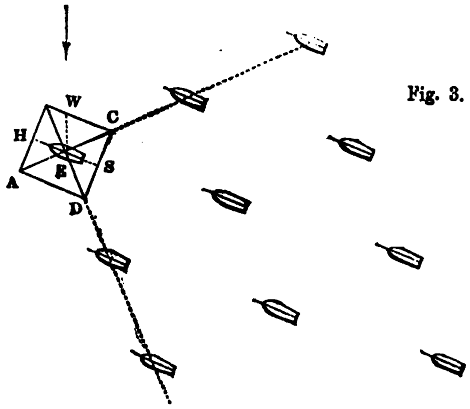


Fig. 3.

The order of battle consists in the ships being drawn up in each other's wake, or in one right line with which the directions of all their keels coincide: they are usually about 50 fathoms from one another, and are nearly close-hauled. The frigates, store-ships, &c., are in lines parallel to that of the line-of-battle ships, and on the side opposite the enemy. A line of ships close-hauled is particularly advantageous as an order of battle both for a fleet to windward, and also for that which is to leeward of its opponent. If a windward fleet were in any other state, the enemy might, by manœuvring, gain the weather-gage, or he might, by being able to approach as near as he pleased, compel the windward fleet to come to an action. By the "weather-gage" is meant the getting between, or the *power* of getting between, the enemy's fleet and the part of the horizon whence the wind blows. Rodney in 1782, and Nelson at Trafalgar, and other admirals have formed their plans of attack on this ground, because a fleet to leeward has difficulty with a fleet lying to windward, in forcing her to an engagement; while, on the other hand, a leeward fleet, of inferior force, has a retreat more open to it. To a fleet being to leeward of an enemy, the only hope of bringing the latter to action is in being able to outsail it, and tack across an enemy's bows; thus getting what is called the weather-gage. In a close-hauled line, also, the sails are disposed so that the ships remain nearly stationary during the action; on which account the line is steadily preserved, and any ship on becoming disabled can be easily replaced by one of those which are in the reserve line.

When the ships of a fleet are in the first or second order of sailing, and it is intended to form the line of battle, it is evident that by simply hauling the wind, or by tacking [Tacking] or veering [Veering], as the case may require, the ships may get into each other's wake in any proposed direction of the line. If it be intended to form the line of battle from the third order, the ships in that wing which is already in a line, in the direction of their keels, must simply haul their wind and get into each other's wake in the proposed direction of the line; each ship in the other wing is then brought into a position nearly at right angles to the direction of the wind, and, as those of the first wing advance, these fall successively into their wake.

When the line of battle is to be formed from the fourth or fifth order, all the ships being supposed to be close-hauled, the formation may take place upon any one of the divisions; the ships of this division are then brought *to* (their motion stopped by bracing some sails so as to be taken aback by the wind while others are kept full), and the other ships are made to take up their proper positions in the

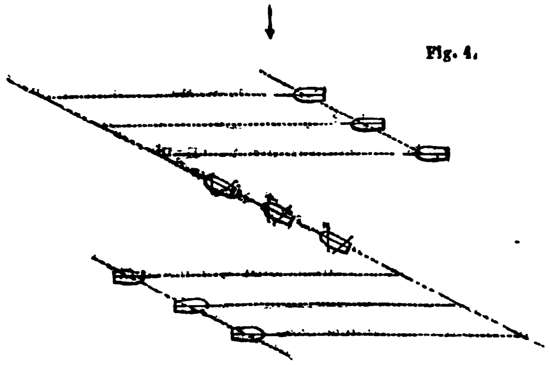


Fig. 4.

prolongation of the line thus formed. If, for example, the fleet consists of ships sailing in three divisions close-hauled, and the line is to be formed upon the centre division, as in the subjoined diagram; then, as soon as this squadron is brought *to*, the ships in the weather division bear away and steer till they get ahead of the centre, when they haul their wind; the lee division tacks and sails on till it gets astern of the centre, and when these ships have hauled their wind the line of battle is formed. In this formation the weather division or column has been made to constitute the van, and the lee column the rear of the line; but it is sometimes thought necessary to make the columns change places, by causing that which is on the weather side of the fleet to become the centre or rear column, or by making the centre or lee column constitute the van of the line. A like interchange of the places of the van, centre, and rear divisions is also, occasionally, made when the fleet is in the order of sailing; and various other evolutions are performed by the ships of a fleet, both while sailing and in the line of battle: the principal of these consist in the several ships tacking, or veering, in succession, and in turning to windward; and there are, besides, the series of movements which are necessary in order to restore the line of battle when disordered in consequence of a shifting of the wind. But the detals of these evolutions can be studied with advantage only in works which are expressly written on naval tactics.

From the order of battle it is necessary to return to some one of the orders of sailing; and with respect to the three first of these, it will be merely necessary for the ships in the line to tack, or bear away, in the assigned directions, increasing or diminishing sail, so that they may arrive in their proper positions nearly at the same time. In returning to the fifth order of sailing, there are two cases, which consist in performing the manœuvres on the same and on the opposite tack. In the first case, should it be required that the van may become the weather squadron, the van and centre tack together and stand on, while the rear proceeds in its actual course; then, when the rear comes successively abreast of the centre and van squadrons, these re-tack, and thus three parallel columns are formed. In the second case, the van being to form the weather squadron, the ships in van first tack in succession, then the ships in the centre, and lastly those in the rear. All then keep on, till the corresponding ships in the different squadrons get abreast of each other, when the order is formed. The evolutions differ, of course, from those just mentioned when the van is to form the lee, and when it is to form the centre squadron.

In the order of retreat before the wind, the ships are drawn up in two equal divisions, in lines making an angle of 135° with each other; the admiral's ship remaining to windward of the rest of the fleet, and being at the angular point.

If a fleet is much superior in force to that of the enemy, it will be of little moment whether it comes to action on the windward or the leeward side; and each of these situations when taken, either by a fleet or a single ship, has both advantages and defects. The advantages of gaining the weather-gage, as it is called, are that in such a situation a fleet may approach that of the enemy, and it may commence the engagement when it shall appear most convenient: ships may be detached to the rear in order to turn the enemy's line and put it in confusion, and a ship may board its opponent almost at will: in firing also, the windward ships are but little incommoded by the smoke. On the other hand, the disadvantages of being to windward are, the difficulty of retreat without passing through the enemy's line; disabled ships cannot quit the line without disordering the rest of the fleet, and in stormy weather the lower-deck ports can seldom be opened. When a fleet is to leeward of that of the enemy, the ships which may be dismasted can be readily drawn away, and the whole fleet may retire if unable to contend against a superior force.

If a fleet to leeward of the enemy's line should attempt to gain the windward side, it should manœuvre so as to delay the engagement for a time in the hope that a change of wind in its favour may take place, and it must then endeavour to take advantage of such change. In these circumstances the commander must however keep the enemy in sight, or at least he must obtain a knowledge of his manœuvres by means of frigates detached for the purpose. If unable to succeed in getting to windward, it should be drawn up on a line as short as possible, in which case, that of the enemy being more extended, some of the ships in it must either take no part in the engagement, or, leaving their line in order to bear down, they will lose the advantage of the wind. On the other hand, a weather fleet should be manœuvred so as always to keep that which is to leeward quite abreast of it; since then, unless the wind should shift, it will continue to hold its position.

When it is desired to bring on an action against a fleet in line on the leeward side, the general rule is that the weather fleet should get abreast of the other, then bear down upon it till within the proper distance, and form in order of battle. Should the leeward fleet bear away at a certain angle with the wind in order to avoid the engagement, the other may bear away at a still greater angle; then, according to the relation between the distance of the fleets from one another and the extent of the weather line of ships, the latter will cut the other in some particular part of its length, and thus compel it to fight in disadvantageous circumstances. Again, if being to leeward of the enemy, it be necessary to avoid an engagement, the only resource is to bear away in order of retreat. If to windward, the fleet should, if possible, in retreating, keep constantly on one tack, in order to avoid the loss of time occupied in going about; but if from want of room it be necessary to change the course, the fleet may be kept on one tack during all the time that the enemy is on the other: for thus the two fleets will be constantly diverging from one another.

It is observed by Mr. Clerk, in his 'Essay on Naval Tactics,' that when an enemy's fleet is to leeward, and in that situation is to be brought to action, both fleets being in line of battle, if the ships in the weather-line bear directly down upon the others, those in the van are liable to be disabled in their rigging; and thus, their motion being retarded, disorder must ensue in the dispositions of the ships which follow them. Precisely the same disadvantages, he adds, attend the method of coming with the whole fleet, in line of battle, obliquely upon the line of the enemy; and to these faulty modes of attack he ascribes the damages which have so frequently been sustained by British fleets at the commencement of actions. The method proposed by that writer for coming to an engagement against a fleet to leeward is similar to that of an attack in oblique order on land, and consists in detaching a squadron for the purpose of attacking some of the rear ships in the enemy's line: the squadron should engage the ships broadside to broadside while the rest of the fleet is at a distance, prepared to send support if necessary. Then, should the van and centre of the enemy's fleet continue its course in order to avoid a general action, those rear ships will be taken: if any of the van ships should tack successively in order to support the rear, some other ships of their line will be in danger of being taken by a second squadron detached from the windward fleet; and if the whole line should tack together, the disorder thence arising might cause the loss of more ships, or might bring on a general action at a disadvantage to the leeward fleet. Lastly, if this fleet should veer, and bear away, the ships would become exposed to a raking fire in their retreat.

The manœuvre of doubling an enemy's line of battle consists in sending ships round by either of its extremities for the purpose of placing some of those in that line between two fires. In order to double a fleet, the ships should advance beyond its van, or fall in its rear, when by tacking or veering according as they are to leeward or windward of the line, they may get into the required position on its opposite side. It is right to observe, however, that this manœuvre ought to be attempted under favourable circumstances only, as the doubling ships are liable to be separated so far from their own fleet as to be prevented from rejoining it; and it is, on the whole, considered more advantageous to double a fleet by its rear than by its van, since in the event of some of the enemy's ships being damaged, and unable to keep up with the rest, such ships may be taken by those which are performing the manœuvre of doubling: should any of these last be separated from their fleet, they can remain in the rear without risk, till an opportunity is offered of rejoining it. At the battle of the Nile (1798), Admiral Nelson doubled the van of the French line, and attacked it on both sides, while the other ships of that line, the whole fleet being at anchor, could afford no assistance. In order to avoid being turned, the largest ships of a fleet ought to be in the van and rear of its line when in order of battle; and the rate of sailing for each should be such that the rear ships may never be astern of the enemy. Care should also be taken that the ships are as close together as possible, that the enemy may not pass between any two of them, and thus break the order of battle.

It is well known, from the records of naval history, that the manœuvre of cutting through the line of an enemy's fleet during an engagement has been several times performed by English commanders since the middle of the 17th century. In an action with the Dutch, in the year 1652, Sir George Ayscue is said to have charged from the leeward through the fleet of the enemy; and in that between the English and Dutch fleets in 1665, the earl of Sandwich cut through the centre of the Dutch line, and caused the disorder which ended in its total defeat: again in May, 1672, Sir Joseph Jordan, of the Blue squadron, having the advantage of the wind, pierced the Dutch fleet and threw it into confusion. But the action which first gave notoriety to the manœuvre was that in which Admiral Rodney gained the important victory over the French fleet commanded by the Comte de Grasse: this action was fought in 1782. The battle in which the brilliant career of Lord Nelson terminated with a decisive victory (1805) owed the success with which it was crowned to the employment of a like mode of attack.

The honour of having been the first to demonstrate fully the principles on which the manœuvres of an attack against fleets to windward or to leeward depend, is generally ascribed to Mr. Clerk of Eldin, who published the first edition of his 'Essay on Naval Tactics' in 1782; and it has been asserted (Playfair's 'Memoir of Mr. Clerk') that Clerk had, in conversation, communicated to Sir Charles Douglas (Rodney's flag-captain) his whole system of tactics in the year preceding that in which the battle with the Comte de Grasse was fought. The accuracy of this assertion has been however disproved by Sir Howard Douglas, in his 'Memoir on Naval Evolutions;' and from an account of the circumstances under which the manœuvre of breaking the French line was performed, as they have been given by Sir Charles Dashwood (one of Admiral Rodney's aides-de-camp on the day of the action), it appears that the idea of the manœuvre was, at the moment, suggested to the admiral by Sir Charles Douglas on perceiving an opening in the French line between two of the ships near its centre. The French fleet was formed in line on a larboard tack, and tended to gain the windward side of the British line, which from the leeward side advanced obliquely towards the fifth ship from the van of the enemy. Signals were then made for the British ships to close up in their line, and the action commenced as the two fleets ranged in opposite directions alongside of each other. When the centre of the British fleet came opposite the third or fourth ship of the French line, Admiral Rodney's ship began a close action within half a musket-shot against the ships of the enemy with which it came successively abreast; and then the opening appearing as above mentioned, the opportunity was seized of passing through it: this was done so near the enemy, that the admiral's ship almost touched the French ship on each side. The ships astern of the admiral followed him closely, and these kept up a powerful raking fire against the ships in the rear division of the enemy's fleet, which, being driven to leeward as the van of the British fleet passed them, broke into two divisions, and made sail before the wind to escape. As soon as the van of the French fleet was left beyond the rear of the still advancing line of British ships, it also broke into two divisions, which retreated in different directions; and then the signal being made for the ships to close up, the British fleet followed in pursuit of that division with which the French admiral had retired. At the battle of Trafalgar (1805), the combined French and Spanish fleets were drawn up in one line, of a crescent form, the convex part being to leeward of the wings, while the fleet of Lord Nelson bore up against it in two lines, in the order of sailing; the leading ships of the lines broke through the fleet of the enemy in two places, and were followed by those of their respective divisions.

The manœuvre of breaking the line of a fleet, like that of attacking in column the line of an army, may not always succeed; and in the action, June 3, 1665, several squadrons passed through and through the Dutch fleet without gaining any advantage. If the line of the enemy is strong, the ships which would pierce it may be placed between two fires, or may be cut off from the rest of their fleet; and perhaps the manœuvre ought not to be attempted unless the line to be broken is already disordered by the action, or unless a favourable opportunity should present itself from negligence or want of skill in the enemy.

Should sufficient reasons exist for performing the manœuvre by a fleet which is to leeward of its enemy, the ships of that fleet should close up as much as possible, and by a press of sail get rapidly through the opening without attempting to engage the ships between which they pass; or each should give the fire of a broadside to one only, reserving the other broadside for the ship with which it is to engage in the new position: this position the ships should of course gain as soon as possible. On the other hand, an attempt to break the line of battle may be counteracted by causing all the fleet, as soon as some of the enemy's ships have got through, to put itself on the same tack as these; by which means some of them will be engaged between two fires, and others will be cut off from all connection with the fleet to which they belong.

When the commander of a ship intends with that ship to come to action with one of the enemy to leeward, he should bear down obliquely towards the latter till he gets nearly into its wake; and when at a proper distance, he may either run up alongside, or having shot a-head, veer and run down on the weather bow: the ship attacked should never be allowed to bring her broadside to bear except when both ships are in parallel positions.

In chasing an enemy's ship which is to windward, the chaser being presumed to sail better than the ship she pursues, it is recommended that the former should stand *on* close-hauled till abreast of the chase; she should then tack, and stand on close-hauled till again abreast; and so on. The ship chased, on the other hand, should, in order to avoid loss of time, continue constantly, if possible, on one course; but it is evident, from the supposed inferiority of her sailing, that she must at length be overtaken by her pursuer.

Such have been, and such would continue to be, the basis of systematic naval warfare with sailing fleets. As regards the Royal Navy, an extended system of manœuvres is called for, inasmuch as more precision in evolutions is attainable by steam-fleets such as will be our future defence.

To this subject both English and French writers have already given their professional attention; and the French admiral, De la Gravière, in his work called 'Guerres Maritimes,' advocates the all-predominant advantages of *speed* over an adversary. It is to Admiral Bowles, C.B., that we owe even the present position of the question of naval tactics; for in 1846 he called attention to the necessity of improved modes of manœuvring steam-vessels before an enemy, as may be seen in his 'Essay on Naval Tactics,' 1846. He was ably seconded by Capt. Dahlgren, U.S. navy, in his work on 'Shells and Shell Guns.' But it is to General Sir Howard Douglas, Bart., that this country owes that development of a system which has been very carefully illustrated by him in numerous diagrams in his 'Naval Warfare.' We refer, therefore, to that work for further details, which would be unnecessary in this Cyclopædia—a work not only valuable to every naval commander, but also to merchant captains, who may resolve to defend the costly ships and steamers committed to their charge. We merely, therefore remark in brief, as a few main features of his most recent opinions—the keeping of a fleet of steamers in well concentrated columns on lines of bearing *en échelon;* the turning an enemy's flank by an oblique movement, as practised on land by Frederick II., by Napoleon at Austerlitz, by Wellington at Waterloo, &c., &c.; and this by bringing an overwhelming force upon the point attacked; the steaming in *line abreast*, in readiness by a simple movement of each ship's head to form *échelon* of ships in line ahead, either as offensive or defensive measures. This consists of a wedge-shaped double line formed on a central ship, in the form of two sides of a right angle, the sides being right angled at such central ship, each ship making with the other an angle of four points. Sir Howard Douglas entirely repudiates the practice of fighting in parallel order.

(*Traité des Évolutions Navales*, par P. Paul Hoste, 1690. A Translation of the same by Captain Boswall, R.N., 1834; Clerk's *Essay on Naval Tactics*, 1790; *L'Art de Guerre en Mer*, par M. le Viscomte de Grénier, 1788; Steele, 1794, Admiral Sir Charles Ekins, *Naval Battles;* and Admiral Sir Howard Douglas's *Naval Warfare with Steam*, 1832 and 1858.)

TÆNIA. [MOULDING.]

TAIL, ESTATE. [ESTATE.]

TAILZIE, in the law of Scotland, is the technical term corresponding with the English word Entail, which now generally supersedes it in colloquial use, even in Scotland. The early history of Entail law in Scotland in some respects resembles that of England, but in later times they diverged from each other. In Scotland there was no early effort, such as the statute of Westminster the Second (13 Edw. I.) favouring deeds appointing a fixed series of heirs, nor does there appear to have been on the part of the judges that inclination to permit perpetuities to be defeated by fictions which was shown in England. Devices, however, of a very similar character to those of the English statute were adopted to defeat attempts by holders under entail to use their lands as if they were absolute proprietors. The first and simplest restriction laid on the destined heirs of an entail was in the form of a mere prohibition, against contracting debt which might occasion the attachment of the estate by creditors, selling the property, altering the order of succession, and the like. A provision of this character, called the "Prohibitive clause," was, however, quite insufficient to accomplish the end; because if a creditor had really attached the estate for debt, or a person had *bonâ fide* purchased it, it was no ground for wresting the title out of his hands, that the proprietor was under a prohibition against permitting such occurrences. A second provision was added, called an "Irritant clause," by which any right acquired contrary to the provisions of the entail was declared to be null. Still this did not effectually intimidate the holder under the entail from making efforts to break it, and did not give the next in succession a sufficient title to interfere. A third provision was added called the "Resolutive clause," by which the right of the person who contravenes the prohibition "resolves" or becomes forfeited. It was then provided by statute (1685, c. 22) that all entails should be effective which contained Irritant and Resolutive clauses, were duly recorded in the Register of Entails, and were followed by recorded saisins containing the Prohibitory, Irritant, and Resolutive clauses. Entails thus became a permanent feature in the institutions of the country. A sort of judicial war was for a time carried on against them, which produced a vast amount of litigation and strife, and placed the titles of property in a precarious and doubtful position. Quite recently, however, the entail law of Scotland has been assimilated to that of England; the method of creating entails has been simplified, and means of barring them provided, so that, except in matters of form, the law of Scotland with respect to entails now closely resembles that of England.

TALAPOINS is the name given by the Portuguese, and after them by other European nations, to the Buddhist priests, or rather monks, of Siam, and is supposed to be derived from the fan which they always carry, usually made of a leaf of the palmyra-tree, and hence, says Crawfurd ('Journal of Embassy to Siam'), denominated by the Sanskrit word *Talpat.* Tal is the common Indian name for the palmyra; and the older travellers give Talapa as the Siamese word for a fan. By the Burmese the Talapoins are said to be called Rahans, whence seems to come the name Raulins, given to them by the Mohammedans; as by the Chinese they are called Ho-changi; in Tibet, Lama-sen or Lamas; and in Japan, Bonzes. (Prevost, 'Histoire Générale des Voyages,' vi.; and 'Christianisme en Chine, en Tartarie, et au Thibet,' par M. Huc, 1857.) In Ceylon the name for the priests is stated by Sir J. E. Tennent, in his 'Christianity in Ceylon,' 1850, to be Samanaros, the name also given to them in Siam; apparently the same word as the Samaneans, or Buddhists of Bahar, quoted by Pliny and Strabo from Megasthenes, B.C. 300.

They are, as has been stated, a species of monks living in communities of from ten to some hundreds, and employing their time in devotion, religious study, and meditation, and in begging, or rather receiving alms, for they are not permitted actually to solicit charity. Their dresses of yellow cotton or silk (which are essential to the priesthood, and the quitting of which is an abandonment of the order) are of the same fashion as those of the Buddhist priests in Ava and Ceylon, and present a highly favourable contrast to the rags and squalidity of the general population. On the other hand, a talapoin is not only separated from society by being condemned to celibacy, and is prohibited from possessing property, but is expected to observe very strictly several of the precepts of the national religion which are very little attended to by anybody else, especially the prohibitions against the slaying of animals (although they will eat them when slain), stealing, adultery, lying, and drinking wine. Sir J. E. Tennent states that they are wretchedly poor, and in point of education rise little above the peasantry, but that they are superstitiously sincere.

TALBOTYPE. [PHOTOGRAPHY.]

TALENT (τάλαντον) was the highest denomination of Greek weights and money, and was also commonly used by Greek writers as the translation of words signifying a certain weight in other languages. It is necessary to observe that the talent is properly only a denomination of *weight*. There was no coin of that name; and when used in reference to money, it meant originally a talent-weight of gold or silver, and afterwards a certain quantity of current money, the weight of which (supposing the real and nominal value of the coin to be the same) amounted to a talent.

1. *The Hebrew Talent, or Kirkar* (כִּכָּר), contained 3000 shekels, and, according to Mr. Hussey's computation, its weight was 93 lbs. 12 ozs avoirdupois, and its value as *silver*-money 396*l.* 5*s.* 10*d.* [SHEKEL.] The Hebrews had no gold money of their own.

II. *The Greek Talent.*—The following were the principal denominations of weight and money among the Greeks :—*ὀβολός, δραχμή, μνᾶ, τάλαντον*, of which the *ὀβολός* was the smallest. Their relative proportions are shown in the annexed table :—

Obol			
6	Drachma		
600	100	Mina	
36,000	6000	60	Talent.

This system prevailed throughout Greece, but the actual values of the talent varied in different states. Most of these variations may be included under two chief standards, namely, the Attic and Æginetan.

1. *The Attic Talent.*—The value of the Attic talent before the time of Solon is a matter on which we possess little historical information, though there is no doubt that previous to Solon the Euboic talent was in use, and coins exist which are held to belong to that period. After Solon had remodelled the coinage, the Attic silver money was celebrated for its purity; and therefore from the coins of that period which still exist we may determine the value of the standard with tolerable certainty. Now the chief coin was the drachma of silver, the average weight of which, from the time of Solon to that of Alexander the Great, is found to be 66·5 grains. From this we get the following values in avoirdupois weight :—

	lb.	oz.	gr.
Obol	..	..	11·08
Drachma	..	..	66·5
Mina	..	15	83·75
Talent	56	15¼	100·32

This was the standard always used for silver money, and was therefore called "the silver standard."

Besides this there was another standard, the chief weight of which was called *the commercial mina* (ἡ μνᾶ ἡ ἐμπορική), and contained 138 drachmæ, "according to the standard weights in the silver mint" (see a decree in Böckh, 'Corp. Inscrip.', i. 123, § 4); that is, not that a commercial mina contained 138 *commercial* drachmæ, but that this was quite a different standard from that used for silver money, its unit being to that of the latter in the ratio of 138 : 100; while the *relative* proportions of the weights were the same in both systems. The following table shows the value of the Attic commercial standard :—

	lb.	oz.	gr.
Obol	..	..	15·29
Drachma	..	..	91·77
Mina	1	4¾	93·69
Talent	75	5¾	14·69

These weights were used for all commodities, except such as were expressly required by law to be sold by the silver standard.

This commercial standard is most probably, as Böckh has shown, the real ancient Attic standard, as it existed before the time of Solon. The purpose of Solon's change was to lower the value of money, in order to relieve debtors. The only direct information we have of the nature of the change is the statement of Plutarch, that "Solon made the mina of 100 drachmæ, which had formerly contained 73," which is probably a mistake made by Plutarch, through not understanding the words of Androtion, whose authority he follows. The true meaning seems undoubtedly to be, that *out of the same quantity of silver* which in the ancient standard made 73 drachmæ, Solon coined 100, or a mina; that is, that he lowered the standard in the ratio of 100 : 73. Now the ratio of the commercial to the silver standard is 138 : 100 = 100 : 72$\frac{32}{69}$. Hence the commercial standard and the old Attic only differed by a small fraction.

Still this ratio of 100 : 73 is a very singular one for Solon to have adopted. Böckh suggested that Solon meant to lower the standard by a quarter, that is, in the ratio of 100 : 75, and that the new coinage (by an accident of not uncommon occurrence in minting) was found, when actually made, to be a little too light, namely, in the ratio of 72$\frac{32}{69}$: 100, or, in round numbers, 73 : 100 to the old money, instead of 75 : 100; but a further investigation has led him to conclude that the true reason was to bring the new system into a definite proportion with the Æginetan which prevailed widely in Greece, and this proportion is as 3 : 5.

The Romans reckoned both the Attic and Euboic talents as equal to 80 Roman pounds (compare Polyb. xxi. 14, with xxii. 26, and Liv. xxxvii. 45. with xxxviii. 38).

The Attic commercial standard underwent an alteration by the edict above referred to, which made

its mina = 150 drachmæ (silver)
its 5 minæ = 6 minæ (commercial)
its talent = 65 minæ (commercial)

In this new standard the five-minæ weight was equal to 7lb. 13¾ oz. 14·96 grs., and the talent to 85 lbs. 2¼ oz. 70·7 grs.

The Athenians took the greatest care of their standards of weight. The principal set were lodged in the Acropolis, and there were other sets in the Prytaneum, at Piræus, and at Eleusis.

The highest coin used by the Athenians was the tetradrachm, or piece of four drachmæ; the mina and talent were never coined, but were paid in drachmæ, oboli, &c. The following table shows the value of all the denominations of Attic silver money, according to the computations of Mr. Hussey :—

	£	*s.*	*d.*	*farthings.*
Chalcus (of copper)				·8125
¼ Obol				1·625
½ Obol				3·25
Obol			1	2·5
Diobolon			3	1
Triobolon			4	3·5
Tetrobolon			6	2
Drachma			9	3
Didrachm		1	7	2
Tetradrachm		3	3	
Mina	4	1	3	
Talent	243	15		

2. *The Æginetan talent.*—Pollux (ix. 76, 86) says that the Æginetan talent contained 10,000 Attic drachmæ, and the Æginetan drachma 10 Attic obols, which would give the ratio of 5 : 3 for that of the Æginetan to the Attic talent. According to this statement, the Æginetan drachma weighed 110 grains English. Now the existing coins give an average of only 96 grains; and the question therefore is whether we are to follow Pollux or the coins. Mr. Hussey takes the latter course, explaining the statement of Pollux as referring to the debased drachma of later times, which was about equal to the Roman denarius. Böckh adheres to the statement of Pollux, explaining the lightness of the existing coins by the well-known tendency of the ancient mints to depart from the full value. He has supported his view by some very strong and ingenious arguments, and on the whole he appears to be right.

There were other talents used by the Greeks and Romans, most of which seem to have been derived from one of these two standards, but the accounts of ancient writers respecting them are very contradictory. Their values are discussed at length by Böckh, Hussey, and Humphrey.

The most important variations of the Æginetan standard were those used in Macedonia, Corinth, and Sicily.

The above talents were all reckoned in silver money. There was also a talent of gold, which was much smaller. It was used chiefly by the Greeks of Italy and Sicily, whence it was called the *Sicilian talent* as well as the *gold talent*. It was equal to 6 Attic drachmæ, that is, about ¾ oz. and 71 grs. It was divided by the Italian Greeks into 24 *nummi*, and afterwards into 12, each nummus containing 2½ *litræ*. When Homer uses the word *talent*, we must always understand by it this small one of gold. In other classical writers the word generally means the Attic talent.

(Böckh, *Metrolog. Untersuch.*; Hussey, *Antient Weights and Money*; Humphrey, *Coin Collector's Manual*, 1853.)

TALES. At common law, when the number of jurymen in attendance was so small, or so much diminished by challenges that a full jury could not be had, a writ (then in Latin) issued to the sheriff, commanding him to summon *such* (tales) other fit persons, &c., for the purpose of making up the jury. The jurors so procured were called talesmen, from the Latin word used in the writ. By the statute 35 Henry VIII., c. 6, the defect of jurors might, at the request of the plaintiff or defendant in an action, be supplied from *such* other able persons of the said county then present, and these were ordinarily called, from the words in the Latin writ, "tales de circumstantibus." Subsequent statutes extended and regulated the application of this statute. The act now in force is the 6 Geo. IV., c. 50, s. 37.

TALIONIS, LEX, the law of retaliation; the notion of which is that of a punishment which shall be the same in kind and degree as the injury. This punishment was a part of the Mosaic Law: "breach for breach, eye for eye, tooth for tooth: as he hath caused a blemish in a man, so shall it be done to him again. Levit. xxiv., 20. The name "talio" occurs in the provisions of the Twelve Tables: it is not there defined what it means, but the signification of the term may be collected from other places. The word contains the same element as the word *talis*, "such," or "like."

TALISMAN, an Arabic word, supposed to be derived from the Greek *telesma* (τέλεσμα), is a figure cast in metal or cut in stone, and made with certain superstitious ceremonies, when two planets are in conjunction, or when a certain star is at its culminating point. A talisman thus prepared is supposed to exercise an influence over the bearer, preserving him from disease, rendering him invulnerable in battle, and so forth. They were probably used originally to avert disease, for we find them mentioned in the history of medicine among all ancient nations. The Egyptians made use of figures of sacred animals, such as the ibis and the scarabæus, which they wore generally suspended from their necks. The Arabs and the Turks did the same, when they were idolaters; but after their conversion to Islam, they used sentences from the Koran, taken chiefly from the surah, or chapter, entitled 'The Incantation.' These they wore inscribed on rolls of vellum or paper, enclosed in a silver box, and suspended from their neck; or else engraven upon a signet ring. Military men used similar sentences from the Koran on the hilt or blade of their swords; on their shields, helmets, and other pieces of armour; or woven into their garments. Christian nations even were not exempt from this superstition. In the middle ages, relics of saints, consecrated candles, and rods, rosaries, &c., were employed, and still are, in Spain and in some parts of Italy.

TALLAGE is derived, according to Lord Coke, from the law Latin word *tallagium*, or *tailagium*, which, as he says, "cometh of the French word *tailer*, to share or cut out a part, and metaphorically is taken when the king or any other hath a share or part of the value of a man's goods or chattels, or a share or part of the annual revenue of his lands, or puts any charge or burthen upon another; so as *tallagium* is a general word, and doth include all subsidies, taxes, tenths, fifteenths, or other burthens or charge put or set upon any man." It was generally however confined in its sense to taxes received by the king. The most important statute on the subject is entitled 'De Tallagio non concedendo,' which was passed in the 34th year of Edward III., to quiet the discontent then universal throughout the kingdom. It had arisen among the commons in consequence of the king having taken a tallage of all cities, boroughs, and towns without the assent of parliament. He was embroiled also with the nobles and landowners, from having attempted, unsuccessfully however, to compel all freeholders of land above the value of 20*l.* to contribute either men or money towards his wars in Flanders. The first chapter of the statute is the most important: "No tallage or aid may be set or levied by us or our heirs in our kingdom without the good will and assent of the archbishops, bishops, counts, barons, knights, burgesses, and other free men of the commons of our kingdom." These words, as Lord Coke says, are "plain without any scruple, absolute without any saving;" and, if there could have been perfect reliance on their operation, must have been entirely satisfactory. But the same king had just violated almost the same engagements entered into by himself only six years before. (25 Edward I., c. 5, 6, 7, 'Confirmationes Chartarum;' 2 Inst., 530.)

TALLOW (French, *suif;* German, *talg;* Italian, *sevo, sego;* Russian, *salo, toplenoe;* Spanish, *sebo*) is animal fat melted and separated from the membranous matter which is naturally mixed with it. When pure, tallow is white, and nearly tasteless; but the tallow of commerce usually has a yellow tinge. It is divided, according to its qualities, into various kinds, of which the best are used for the manufacture of candles, and the inferior for making soap, dressing leather, greasing machinery, and some other purposes.

A large proportion of the tallow used for making candles in this country is of home production. It is fitted for use by the *renderer*, who chops into pieces the fat and suet received from the butchers, and boils it in water, by which operation the greater part of the fat is melted out from the membranes, and floats to the top, whence it is removed by skimming. The remaining fat is subsequently squeezed from the membranes by a powerful press, leaving the membranous matter in the form of a cake or block, of a dark colour, which is called *graves*, or *cracklings*, and which, when macerated in warm water, softens and swells, and is used as food for poultry, dogs, and other domestic animals. The operation of *rendering* should be performed as speedily as possible after the removal of the fat from the carcass, because the fibrous and fleshy matter mixed with it tend to promote putrefaction.

Almost all our imported tallow is brought from Russia, where this article is produced in enormous quantities. About 250,000,000 lbs. of tallow are furnished annually to the rest of the world, providing the chief supply of soap and candles to England, France, Germany, Scandinavia, Italy, and the other countries of Europe; and this is all in addition to the large quantity consumed by the Russians themselves. Nearly the whole of this quantity is furnished by the Pontine steppes, in the southern part of European Russia. The large tallow-manufactories, or *salgans*, as they are called, are exclusively in the hands of the natives of Great Russia, who buy the cattle by thousands, and, after fattening them for a season, drive them to the salgans to be slaughtered. The salgans, to which the tallow-boilers usually begin to drive their oxen in small numbers towards the close of summer, generally consist of a spacious court-yard surrounded by the buildings necessary for the manufacture: embracing shambles for slaughtering the oxen, houses containing enormous boilers to boil down the flesh, places for salting the hides, and counting-houses and dwellings for the workmen. In the summer these establishments are untenanted, except by dogs and birds of prey, which hover about all the year round, attracted by the nauseous smell, which, however alluring to them, is disgusting to a visitor and distressing to the oxen. The business is generally carried on during the rainy season. The actual slaughtering is performed in so rude and unartificial a manner as to occasion much needless suffering to the beasts. After the carcasses are skinned, three or four poods of flesh are cut off from the loins and back for sale in the bazaar as meat, there being little fat in those parts of the body; but owing to the barbarous method of slaughtering, this meat is so much injured that none but the poor will buy it. The remainder of the carcass is cut up, and everything, excepting the intestines, which are given to the pigs (of which a considerable number are always kept at the salgan to fatten during the season), is thrown into the boilers, of which there are from four to six in every salgan, each large enough to contain the flesh of ten or fifteen oxen. A little water is put into the boiler, to prevent the "soup," as its contents are termed, from burning. The fat, as it collects at the top, is skimmed off with large ladles; and before it is quite cold it is poured into the casks in which it is afterwards shipped. The first fat which comes off is the best, and is quite white; while that which follows has a yellowish tinge. When there are not sufficient casks at hand, the hides of the slaughtered oxen are sewn up, and the tallow is poured into them. A further supply of fat, but of very inferior quality, is subsequently obtained by subjecting the mash of bones and flesh to huge presses. This tallow, which is rarely exported, is of a dark brown colour, and is used for greasing wheels and for other coarse purposes. An ox in good condition will yield from seven to eight poods (250 to 290 lbs.) of tallow, which is generally worth from eleven to fifteen rubles a pood. The article is always so greatly in demand, that the merchants often pay part of the price for it while the oxen are yet grazing on the steppes.

The merchants of St. Petersburg divide the tallow which they receive from the interior into white and yellow candle-tallow, and common and Siberian soap-tallow; the latter, which is considered the best tallow for soap-making, being brought by several rivers from Siberia to the lake Ladoga, and thence to the Neva by the canal of Schlusselburg. An *ambare*, or warehouse, is appropriated to the reception of the tallow on its arrival, in which it is selected and assorted (or *bracked*) according to quality, after which the casks are marked with the quality, the date of the selection, and the name of the *bracker* or selector. The white tallow is usually brought in conical casks, 2½ feet in diameter at the largest and 1¼ at the smallest end; but the yellow tallow is commonly in casks of the more usual shape. Yellow candle-tallow, when good, should be clean, dry, hard when broken, and of a fine yellow colour throughout. The white candle-tallow, when good, is white, brittle, hard, dry, and clean. The best white tallow is brought from Woronesch. Soap-tallow, however, is said to be better the more greasy and yellow it is. M'Culloch states that 120 poods of tallow, gross weight (of which the cask is usually about 10 per cent.), make a Petersburg last, and 63 poods an English ton.

Different kinds of tallow melt and retain their fluidity at very different degrees of temperature; the fat which is deposited about the kidneys being, in all animals, harder than that found in the cells of the bones, and especially than the half-oily fat found in the muscles and other soft parts; while the fat of some animals is harder than that of others—that of the sheep and deer, for example, congealing much sooner than that of the ox or horse. According, therefore, to the different kinds of fat which may enter into its composition, tallow will be found to vary considerably in fusibility; but 92° is the heat generally given as its melting-point, though Aikin states that he had seen a boiler-full of tallow perfectly fluid at 72°, and even then not sufficiently cooled to be made into candles; nor was this case, he observes, considered remarkable, "whence we may conclude that tallow, made into candles and exposed to the air, loses much of its fusibility."

The chief uses of tallow are described under CANDLE MANUFACTURE and SOAP MANUFACTURE.

During a long period of years, foreign tallow paid an import duty of 1*s.* 6*d.* per cwt., and tallow from the colonies a duty of only 1*d.* These duties were repealed in 1860, among other fiscal changes made by Mr. Gladstone.

The importation of tallow has now reached 160,000,000 lbs. annually. The exact figures for 1860, and the countries whence imported, were as follow :—

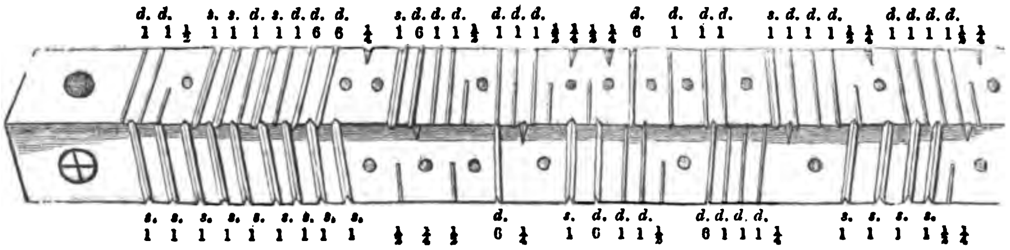
From Russia . . .	1,082,663	cwts.	
,, Australia . . .	12,005	,,	
,, South America . .	146,957	,,	
,, Other countries . .	188,483	,,	
	1,430,108	,,	or, 160,172,096 lbs.

TALLY. This word appears to be derived from the French *taille*, or *tailler*, each of which expresses the idea of cutting or notching.

The use of notched sticks or tallies may be traced to a very remote period, and there is reason to believe that they were among the earliest means devised for keeping accounts. Some writers conceive that the

Greek symbolum (σύμβολον) was in some cases a species of tally, which was used between contracting parties; being broken in two, and one-half given to each. Upon tablets of wood called *axones* the Athenians inscribed the laws of Solon; and the ancient Britons used to cut their alphabet with a knife upon a stick, which, thus inscribed, was called *Coelbren y Beirdd*, "the billet of signs of the bards," or the Bardic alphabet. These sticks were commonly squared, but were sometimes three-sided; each side, in either case, containing one line of writing. Another illustration, of later date, is the clog-almanac, described by Dr. Plot, in 1686, as then common in Staffordshire. Such calendars, which had the various days marked by notches of different forms and sizes, were sometimes made small enough to carry in the pocket, and sometimes larger, for hanging up in the house. Similar calendars are said to have been formerly used in Sweden. Perhaps the most curious of these tallies is the Saxon Reive-Pole, which, down to a recent period, was used in the Isle of Portland for collecting the yearly rent paid to the crown as lord of the manor. This rent, which amounts to 14*l.* 14*s.* 3*d.*, is collected by the reive, or steward, every Michaelmas; the sum which each person has to pay being scored upon a squared pole, a portion of which is represented in the subjoined cut, with figures to mark the amount indicated by each notch. "The black circle at the top denotes the parish of Southwell, and that side of the pole contains the account of the tax paid by the parishioners; each person's account being divided from that of his neighbour by the circular indentations between each. In the present instance the first pays 2½*d.*, the second 4*s.* 2*d.*, the next one farthing, and so on." The other side of the pole which is represented in the cut is appropriated to the parish of Wakem, of which the cross within a circle is the distinctive mark.

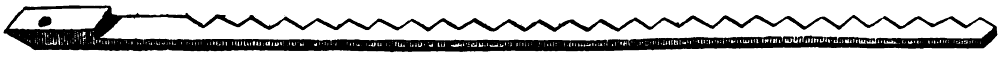
Fig. 1.


d. d. s. s. d. s. d. d. d. s. d. d. d. d. d. d. d. d. d. d. s. d. d. d. d. d. d. d.
1 1 ½ 1 1 1 1 1 6 6 ¼ 1 6 1 1 ½ 1 1 1 ½ ¼ ½ ¼ 6 1 1 1 1 1 1 1 ½ ¼ 1 1 1 1 ½ ¼
s. s. s. s. s. s. s. s. s. d. s. d. d. d. d. d. d. d. s. s. s. s.
1 1 1 1 1 1 1 1 1 ½ ¼ ½ 6 ¼ 1 6 1 1 ½ 6 1 1 1 ¼ 1 1 1 1 ½ ¼

Saxon Reive-Pole used in the Isle of Portland.

The tallies used in the Exchequer (one of which is represented by *fig.* 2) answered the purpose of receipts as well as simple records of matters of account. They consisted of squared rods of hasel or other wood, upon one side of which was marked, by notches, the sum for which the tally was an acknowledgment; one kind of notch standing for 1000*l.*, another for 100*l.*, another for 20*l.*, and others for 20*s.*, 1*s.*, &c. On two other sides of the tally, opposite to each other, the amount of the sum, the name of the payer, and the date of the transaction, were written by an officer called the writer of the tallies; and, after this was done, the stick was cleft longitudinally in such a manner that each piece retained one of the written sides, and one-half of every notch cut in the tally. One piece was then delivered to the person who had paid in the money, for which it was a receipt or acquittance, while the other was preserved in the Exchequer. Madox observes, respecting these rude and primitive records, "The use of them was very ancient; coeval, for aught I know, with the Exchequer itself in England." They were finally discontinued at the remodelling of the Exchequer in 1834; and it is worthy of recollection that the fire by which the Houses of Parliament were destroyed was supposed to have originated in the over-heating of the flues in which the discarded tallies were being burnt. Clumsy as the contrivance may appear, tallies were effectual in the prevention of forgery, since no ingenuity could produce a false tally which should perfectly correspond with the counter-tally preserved at the Exchequer; and no alteration of the sum expressed by the notches and the inscription could pass undetected when the two parts of the stick were fitted together. The officers of the Exchequer, commonly called *tellers* (talliers), as well as several other functionaries, derived their name from the word tally.

Fig. 2.



Exchequer Tally.

Tally Trade.—The word *tally* has come to mean a *counterpart*, although no cutting of a wooden tally is necessary. Thus, in the tally-drapers' trade carried on at the present time in various parts of the kingdom, there are 10,000 or 12,000 persons employed in the distribution of clothing or drapery which has cost them 7,000,000*l.* or 8,000,000*l.* annually, and which is re-sold by them on the tally system. They receive weekly payments from their customers; and these payments are recorded on a *tally* and a *counter-tally*; these are books, one of which is kept by the buyer and the other by the seller. Here the tally is a record of payments, as in the olden days, but maintained in a different form. There are tally-shops, also, where weekly payments are taken for goods bought; these differ from the tally-drapery trade chiefly in this—that in the latter the goods are taken round by the tally-men, who keep no shops.

TALMUD. [HEBREW LANGUAGE.]

TAMARINDS, *Medical Properties of.* Of the two varieties of the only species of this genus, the fruit is much larger in the East Indian than the West Indian. The shell being removed, there remains the flat square hard seeds, imbedded in a pulp, with membranous fibres running through it. In the East Indies the pulp is dried, either in the sun, and this is used for home consumption, or with salt added, and dried in copper ovens, which kind is sent to Europe. (Crawfurd's 'Indian Archipelago.') This sort, called natural tamarinds, is much darker and drier than the West Indian, which are called prepared tamarinds.

The West Indian tamarinds reach maturity in June, July, and August, when they are collected, and the shell being removed, they are put into jars, either with layers of sugar put between them, or boiling syrup poured over them, which penetrates to the bottom. Prepared tamarinds, therefore, contain much more saccharine matter than the others. According to Vauquelin, prepared tamarinds contain per cent. citric acid 9·40, tartaric acid 1·55, malic acid 0·45, bitartrate of potash 3·25, sugar 12·5, gum 4·7, vegetable jelly (pecten) 6·25, parenchyma 34·35, water 27·55. This prepared pulp has a pleasant astringent taste, with a somewhat vinous odour.

It presents an example of one of those natural combinations of gummy, saccharine, and acid principles which are of such great utility in hot climates. It is used not only in India, but in Africa, as a cooling article of food, and the travellers across the deserts carry it with them to quench their thirst. In Nubia it is allowed to stand in the sun till a kind of fermentation takes place: it is then formed into cakes, one of which dissolved in water forms a refreshing drink. In India a kind of sherbet is made with it, and by the addition of sugar it becomes a source whence vinegar is readily obtained. In the fevers and bilious complaints, and even dysenteries of those climates, it proves highly serviceable; in small quantity it acts as an astringent, but in larger it proves laxative. Boiling water poured over tamarinds yields a drink which is very grateful in the inflammatory complaints of our own country, particularly in the bilious fevers of autumn. An agreeable whey may be made with it, by boiling two ounces of tamarind-pulp with two pints of milk. Tamarinds may advantageously be added to curries, which should always have a vegetable acid as an ingredient. Tamarinds are frequently given along with senna, but they are said to lessen its purgative property. They form an ingredient in the *confectio sennæ* and *confectio cassiæ*.

In times of scarcity in India the seeds are eaten, being first toasted and then soaked for a few hours in water, when the dark skin comes easily off; they are then boiled or dried, and taste like common field-beans.

TANACETIN. A bitter and crystallisable substance found in the flowers of the tansy (*Tanacetum vulgare*).

TANGENT. In the article CONTACT we have given the first notion on this subject, which we now resume in a somewhat more general manner, annexing the usual details of formulæ, but without proof.

It is usual to apply the word tangent to the tangent *straight line* only, on which see DIRECTION: generalising the definition, it will be as follows:—Of all curves of a given species, or contained under one equation, that one (B) is the tangent to a given curve (A) at a given point, which passes through that given point, and is nearest to the curve (A): meaning that no curve of the given species can pass through the given point, so as to pass between (B) and (A), immediately after leaving the point at which the two latter intersect.

To ascertain the degree of contact of two curves which meet in a point, proceed as follows. Let $y=\phi x$ and $y=\psi x$ be the equations of the curves, and a the abscissa at the point of contact; so that $\phi a=\psi a$. At the point whose abscissa is $a+h$, the difference of the ordinates of the curves is, by Taylor's theorem,

$$(\phi'a-\psi'a)\,h+(\phi''a-\psi''a)\,\frac{h^2}{2}+(\phi'''a-\psi'''a)\frac{h^3}{2.3}+\ldots$$

as to which it will be found that h can be taken so small that the series shall be convergent. Now of two series of the form $\text{A}h^m + \text{B}h^{m+1} + \ldots.$ the value of that in which m is the greater will diminish without limit as compared with the other, when h diminishes without limit. Consequently, every curve $y=\psi x$, which has $\psi' a=\phi' a$, will approach, before the point of contact is attained, nearer to $y=\phi x$ than any other in which $\psi' a$ is not $=\phi' a$. Again, when $\phi' a=\psi' a$, those cases of $y=\psi x$ in which $\psi'' a=\phi'' a$, will approach nearer to $y=\phi x$ than any in which $\phi'' a$ is not $=\psi'' a$; and so on. Hence, to make $y=\psi x$ have the closest possible contact with $y=\phi x$ when $x=a$;—give such values to the constants in $y=\psi x$ as will satisfy as many as possible of the equations $\phi a=\psi a$, $\phi' a=\psi' a$, $\phi'' a=\psi'' a$, &c. consecutively from the beginning. This is a brief sketch, which can be filled up from any elementary work; and the following are the principal results :—

1. When the string of equations is satisfied up to $\phi^{(n)}a=\psi^{(n)}a$, the contact is said to be of the nth order.

2. In contact of the nth order, the deflection $\phi(a+h)-\psi(a+h)$ diminishes with h^{n+1}, and vanishes in a finite ràtio to it.

3. In contact of an even order, the curves intersect at the point of contact; in contact of an odd order, they do not intersect at that point.

4. When curves have a contact of the nth order, no curve, having with either a contact of an order inferior to the nth at the same point, can pass between the two.

5. A straight line, generally speaking, can have only a contact of the first order with a curve; and the equation to the tangent straight line of the curve $y=\phi x$, when $x=a$, is $y-\phi a=\phi' a(x-a)$. But if it should happen that $\phi'' a=0$, $\phi''' a=0$, &c., up to $\phi^{(n)}a=0$, then for that point the tangent has a contact of the nth order. Thus, at a point of contrary flexure the tangent has a contact of the second order, at least, with the curve.

6. A circle, generally speaking, can be made to have a contact of the second order with a curve, and the equation of the most tangent circle, or circle of CURVATURE, to the curve $y=\phi x$, at the point $x=a$, is

$$\left(x-a+\frac{\phi' a\,(1+\overline{\phi' a}^{\,2})}{\phi'' a}\right)^2+\left(y-\phi a-\frac{1+\overline{\phi' a}^{\,2}}{\phi'' a}\right)=\frac{\left(1+\overline{\phi' a}^{\,2}\right)^3}{\overline{\phi'' a}^{\,2}}$$

This circle cuts the curve, generally speaking: if not, as for example, at the vertices of an ellipse, it is evidence that the circle has a contact of some higher and odd order. The centre of the circle of curvature is a point on the normal, being that at which the normal touches the evolute. [INVOLUTE AND EVOLUTE.]

Not only is the term tangent most generally applied to the closest straight line only, but frequently only to that portion of the straight line which falls between the point of contact and the axis of x. Again, the normal is a straight line perpendicular to the tangent, drawn through the point of contact: but this term also is frequently applied only to that portion which falls between the point of contact and the axis of x. It is with reference to this limitation that the terms subtangent and subnormal are to be understood: the first meaning the distance from the foot of the tangent to the foot of the ordinate; the second that from the foot of the ordinate to that of the normal. The formula for the subtangent is $-\phi a\div\phi' a$; that for the subnormal $\phi a\times\phi' a$. The sign determining the mode of taking the line from the foot of the ordinate.

Let β be the angle made by the tangent with the axis of x; usually the angle made by that part of the tangent which has positive ordinates with the positive side of the axis of x. Then β, at the point whose abscissa is x, is determined by the equation

$$\tan\beta=\frac{dy}{dx};\ \text{and subtangent}=-y\frac{dx}{dy},\ \text{subnormal}=y\frac{dy}{dx}.$$

If we take the more general mode of measurement proposed in SIGN, this equation remains equally true. Now, keeping strictly to that mode, let β be the angle made by the tangent with the axis of x, θ the angle made by the radius vector r with the axis of x, and μ that made by the tangent with the radius vector. It will be found, then, that in all cases

$$\mu=\beta-\theta\quad,\quad\tan\mu=r\frac{d\theta}{dr}.$$

Unless the mode of attributing signs be carefully attended to, these last equations, though always considered as universally true, are not so in reality.

TANGUIN. A poisonous crystalline bitter substance found in the Tanghin of Madagascar (*Cerbera Tanghin*). Its composition is not known, but it appears to contain no nitrogen. [CERBERA TANGHIN, in NAT. HIST. DIV.]

TANK. The sense usually attached to this word, in England, is that of a rather large vessel, for holding water or other liquids, either placed above or below the ground; in India, the word is applied to the receptacles formed for the purpose of storing rain-water, some of which have an area of 364 (Dilwara) or 437 acres (Kalingur), with enclosure dykes of 38 feet in height.

Tanks intended to hold rain-water collected from houses, or the drainage water of farm yards in agricultural districts, are rarely made of a greater capacity than 50 or 60 cubic yards; and they are constructed of the most impermeable hydraulic masonry that can be obtained; but precautions must always be taken that the materials so employed should not be of a nature to affect the chemical properties of the waters. Brickwork set in Roman cement is, for instance, preferable for such uses to masonry of limestone, set in ordinary lime mortar; and a backing of good clay puddle is preferable to one made of concrete. Provision must be made for fixing the suction pipes of the pumps, for connecting the inlet and overflow pipes, and for means of access for examination and repair; ventilation pipes must also be provided. As it almost always happens that dead leaves, or other organic impurities, are carried into tanks of the description under consideration, it is advisable, if the water be required for domestic use, to provide some means of filtration for the water, and this object is effected in many very ingenious manners, two of which may here be mentioned. For instance, in the great chalk plateau of Upper Normandy the rain water tanks are sunk into the boulder clay, or the chalk, as the case may be, and they are made of sufficient dimensions to allow of the formation of a subsidiary lateral chamber, shut off from the body of the tank by a cross wall of a porous material, through which the water from the larger chamber filters into the subsidiary one; the suction pipe being placed in the latter, and the inlet pipes in the larger chamber. The other description of rain water tank is used in Venice, and it is formed by firstly making a large watertight enclosure, usually circular in plan, and then an inner, concentric wall is built, leaving a large annular space between them: this annular space is filled in to a certain height with filtering materials of sand, gravel, &c., through which the water passes until it reaches a series of holes made in the lower portion of the inner wall; it then accumulates in this species of well, from whence it is drawn by means of buckets. It must, however, always be observed that rain waters so stored are not of a proper quality for human consumption, and that they should be exclusively applied to washing, or to analogous household purposes.

The large vessels used for storing oils, or for the various operations of manufacturing chemistry, are made of iron, wood lined with lead, of zinc, or of other materials according to the nature of the liquids to be contained. The principles of their construction are derived from the ordinary laws of HYDROSTATICS.

As to the Indian catch-water tanks it may be observed that they are in fact RESERVOIRS, and the remarks made under that head will apply to them. Generally speaking the tanks in question are principally used for irrigation, and their dams are formed of earth-work faced towards the up stream with stone, either laid dry, or with mortar. They are provided with overflow dams, escape weirs, sluices, and all the ordinary appliances of reservoirs; and they would appear to have been constructed upon the same principles at the present century as they were in the remotest antiquity. Much information on this subject is to be found in General Baird Smith's works on 'Irrigation,' and in the 'Selections from the Records of the Bombay Government,' or in the 'Selections from Public Correspondence,' published by authority of the late East India Company.

Agricultural Tanks are sometimes large open receptacles, or ponds, formed by excavating the ground and disposing the removed earth in the form of banks to retain the water; but the tanks which will here be especially treated of are the smaller covered reservoirs used to collect and retain liquid manure.

These tanks are usually constructed of an oblong shape, of brick well cemented, with one or more divisions, and capable of containing at least ten times as many hogsheads as there are heads of cattle on the farm. They are vaulted over, having a small aperture, in which a pump is placed, sufficient to allow a man occasionally to clear out the sediment, when the liquid has been pumped up. The form preferred is that of a cube, or rather that of several cubes in succession. A tank for a farm of 200 acres of arable land should be 15 feet wide, 15 deep, and 45 long, giving 3 cubes of 15 feet, or a cavity capable of containing upwards of 10,000 cubic feet of liquid. In this tank the urine is diluted with water to prevent too rapid decomposition, and also to retain the ammonia which is formed; for which purpose gypsum and sulphate of copper are sometimes put into the tanks. In very porous soils the bottom and sides must be puddled, to keep in the liquid; and it may be advantageous to build the walls in cement altogether. The liquid from the yards and stables is carried into the tank by a main drain constructed of brick or stone, and which receives a number of smaller drains from every part of the yards and cattle-sheds. Thus the litter in the yard is always dry, and none of the richness of the manure is lost by evaporation.

Sometimes the tank is vaulted like a cellar under the cow-house and stables, which are washed out twice every day, and all the dung and water are swept into a cess-pool communicating with the tank. A very diluted, but rich liquid soon fills the first division of the tank: a sluice is then shut, and the next washings run into a second division, and when that is full, into a third. In the meantime the contents of the first tank have undergone a certain fermentation, by which the ammonia first evolved has become mild and impregnates the water. It is then in a fit state to be carried on the land in tubs or water-carts. When properly diluted, it accelerates vegetation in a surprising degree; but if put on fresh, it burns the grass or any vegetable it touches, because the ammonia is in a caustic state. If a cow drop her urine in a field in a hot summer's day, all the grass it has touched becomes yellow and is burned up: but if the same happen in rainy weather, the spot soon becomes very green, and the grass luxuriant; because, in this case, the urine is amply diluted and its caustic nature corrected. Those who live near gas-works may collect the ammoniacal gas-water in a tank, and, by the addition of sulphuric acid in very small quantities, they may produce a very fertilising liquid, which will stimulate vegetation, and be a very good manure.

The necessary concomitant of a tank, whether for water or manure, is a water-cart, that is, a large cask put upon wheels to bring water from some distance. When there are no means of bringing water in pipes, a water-cart is quite indispensable. It is simply a cask placed on the frame of a cart, with a plug-hole in the end or lower part, from which the water may be let out by a cock, or drop on a flat board or into a bucket with holes, so as to spread it about. The plug-hole is shut by a valve inside, which can be opened by means of a string, the pressure of the liquid keeping it close to the plug-hole.

Many of the artificial manures would make excellent liquids by merely mixing them up with water in a tank, and allowing a certain degree of fermentation to take place. Thus nothing is lost, and all volatile substances are taken up by the water. The soluble portions are dissolved and the earthy matters diffused, so as to be more equally spread over the land.

When a farm-yard is situated on a hill, and there are fields or pastures on a lower level, at no great distance from it, the liquid from the tank may be conducted by channels lined with clay, having small sluices to direct the streams to any particular field. It may thus be made to irrigate temporarily a considerable surface, which it will greatly enrich. It may be led into the common furrows between the lands or stitches in ploughed land, and allowed to soak in them, and then it can be spread with the earth of the furrow, by means of broad shovels, over the growing crops, and will greatly invigorate them.

Hitherto the experience in this country of liquid-manure tanks is of limited extent, but the general impression is growing, that by covered yards and box-feeding the litter may so absorb all the urine and excrement of the animals, that tanks will be unnecessary.

TANNIC ACID, TANNIN. One or other of these bodies is found, to a greater or less extent, in most vegetable substances. The name *tannin* is derived from the fact that it is the only active constituent in the various barks, &c., used in the familiar operation of making leather, or *tanning*.

Tannin is an acid body; and inasmuch as researches upon the tannin obtained from various sources have proved that it is not in all cases identical, but that several modifications exist, the names *gallotannic acid* (from nut-galls), *caffotannic acid* (from coffee), *quinotannic acid* (from cinchona bark), *quercitannic acid* (from oak-bark), &c., have been introduced.

Tannic acid is a powerful astringent, and hence has long been used in medicine. For this purpose it is always extracted from nut-galls. The galls are reduced to coarse powder, and digested in a percolator with ether which has been previously mixed and shaken with water. In the lower part of the vessel two strata of liquid appear; the heavier is a strong solution of tannic acid, by evaporating which, the acid is obtained, as a colourless or slightly yellowish friable mass, which does not crystallise, but somewhat resembles dried gum.

The *gallotannic acid* thus obtained is readily soluble in water: the solution has an astringent but not a bitter taste: it reddens vegetable blues, and decomposes alkaline carbonates with effervescence; weak alcohol dissolves it, but ether only slightly. When the aqueous solution is exposed to the air, especially if the temperature be high, oxygen gas is absorbed, and an equal volume of carbonic acid gas evolved, while the gallotannic acid is converted into gallic and ellagic acid. Gallotannic acid precipitates gelatin from solution; the compound has been called *tannogelatin*, and when the acid is in excess a viscid elastic mass is formed, which contains about half its weight of gallotannic acid. When the liquid from which the gelatin is precipitated is heated to ebullition, the tannogelatin is re-dissolved. Gallotannic acid also precipitates albumen and starch. Boiled with dilute sulphuric or hydrochloric acids, gallotannic acid splits up into gallic acid and glucose.

When dried at 212° gallotannic acid consists of $C_{54}H_{22}O_{34}$.

Gallotannic acid combines with the alkalies to form salts, which are called *gallotannates*, and it precipitates most metallic oxides and organic bases from solution. The salts of protoxide of iron suffer no change when a solution of gallotannic acid is added to them; but by exposure to the air a deep bluish-black precipitate is formed. Gallotannate of peroxide of iron, formed by the action of the acid on a persalt of the metal, is the basis of writing-ink, and is a black pulverulent precipitate.

Gallamic or *tanningenamic acid* ($C_{14}H_7NO_8 + 3\,Aq$) is a product of the action of ammonia on gallotannic acid. It crystallises from alcohol in beautiful rectangular plates.

Tannomelanic acid is a dark ulmin-like substance formed when gallotannic acid is boiled with a concentrated solution of potash in a vessel open to the air. If the potash be dilute, a portion of the acid is oxidised to *tannoxylic acid*. The constitution of these acids has not been satisfactorily ascertained.

Sumach-tannic acid, from various species of *sumach*, is identical with gallotannic acid.

Cachoutannic acid or *mimotannic acid*. Obtained from the well-known astringent substances KINO and CATECHU by the displacement process previously described. It differs from gallotannic acid in not giving a precipitate with solution of tartar emetic, and in giving with persalts of iron a grayish-green precipitate. Moreover, it does not yield pyrogallic acid when heated. Its composition is said to be $C_{36}H_{18}O_{16}$. In other respects it resembles gallotannic acid.

Tanningenic or *catechucic acid*, called also *catechin* ($C_{40}H_{18}O_{16}$?), is another tannic acid contained in catechu. It is part of the insoluble portion which is left on digesting catechu in cold water. It may be dissolved in boiling water, and decolorised by animal charcoal: on cooling, it deposits in colourless granular crystals. It is tolerably soluble in alcohol; less so in ether. Heated to 422° Fahr., it fuses, and at a higher temperature is decomposed, yielding *pyrocatechin* or *oxyphenic acid* ($C_{12}H_6O_4$). Dilute acids dissolve it; concentrated acids decompose it; hot nitric acid converts it into oxalic acid. It does not form definite compounds with bases; gives a deep green colour to persalts of iron, but precipitates neither lime-water, baryta-water, tartar-emetic, starch, gelatin, or the alkaloids.

Rufocatechucic acid, or *rubinic acid* is a red, amorphous, flocculent precipitate, slowly deposited from a solution of tanningenic acid in an alkaline carbonate. It forms red slightly soluble salts with bases.

Japonic acid is a black substance formed on exposing to the air a solution of tanningenic acid in caustic potash. It is insoluble in cold water, and gives black precipitates with most of the metals.

Caffotannic, *cafeic*, or *chloroginic acid* ($C_{70}H_{38}O_{34}$?), occurs in coffee berries as a double salt of potash and caffeine, and combined also with lime and magnesia. It may be precipitated by subacetate of lead from an alcoholic infusion to which water has been added to separate resinous matter. The lead precipitate suspended in water and treated with sulphuretted hydrogen, and the filtrate evaporated, yields a semi-crystalline mass of caffotannic acid. It is very soluble in water, less so in alcohol, has an astringent taste, and strongly reddens litmus-paper. By heat it gives oxyphenic acid and an odour of burnt coffee; and by distillation with peroxide of manganese and sulphuric acid, yields kinone. It does not act upon ferrous salts, but to the ferric salts a green colour is imparted. It does not precipitate tartar emetic or gelatine, but throws down quinine and cinchonine from solutions. The *caffotannates* have been but little studied. If the above formula be correct, caffotannic acid is obviously a homologue of gallotannic acid, the difference being eight equivalents of C_2H_2.

Viridic acid ($C_{28}H_{14}O_{16}$?) is a product of the oxidation of caffotannic acid in the presence of ammonia. It is precipitable by subacetate of lead, and gives deep green solutions with the alkalies.

Morintannic acid, from *yellow wood* or *fustic* (*Morus tinctoria*). This acid often forms considerable deposits in the logs of fustic, and after being purified by crystallisation from water is obtained in minute prisms. It has a sweetish and yet astringent taste; is soluble in alcohol, ether, and wood spirit, but insoluble in turpentine and the fixed oils. By distillation it yields phenic and oxyphenic acids and much charcoal. The *morintannates* have not received much attention. The solution of the acid in potash absorbs oxygen from the air, blackens, and *moroxylic* acid is probably formed.

Rufimoric acid is deposited in crystalline grains on exposing to the air a solution of morintannic acid in sulphuric acid; or on boiling the same acid with dilute hydrochloric acid. When dry it forms a deep red amorphous powder, very soluble in alcohol, less so in water, and only slightly so in ether. It is very soluble in a weak solution of ammonia, and the liquid has a dark purplish colour. In composition it differs but slightly from morintannic acid, but both bodies require farther investigation.

Moric acid, or *morin* ($C_{30}H_{14}O_{18} + 2\,Aq.$), as a lime salt, is deposited on cooling an infusion of fustic. Liberated by oxalic acid in a boiling alcoholic solution and precipitated by water, it occurs as a white crystalline powder that becomes slightly coloured on exposure to the air. It is almost insoluble in cold water, only slightly soluble in boiling water, and very soluble in alcohol or ether.

Quercitannic acid. This is the variety of tannic acid contained in oak bark. According to Stenhouse it differs considerably from that of oak galls (gallotannic acid). It cannot be made to yield gallic acid, nor does it give pyrogallic acid by dry distillation. In other respects it resembles gallotannic acid.

The tannic acid (*boheic acid*) contained in *black tea* (*Thea bohea*) appears to be identical with that of oak bark.

Cinchotannic, *kino-* or *quino-tannic acid*, occurs, along with kinic acid, combined with alkaloids in the cinchona barks. It resembles gallotannic acid in precipitating gelatin, starch, and albumen from their solutions; with tartar-emetic it gives a grayish-yellow precipitate, and colours persalts of iron green. Its solution absorbs oxygen from the air, especially if it be alkaline, and a deep red coloured body termed *red cinchone* is formed. By dry distillation the latter body furnishes pyrogallic acid.

Other tannic acids. Astringent principles, termed tannic acids, have been found in plants other than those above described. The following are the names and sources of these acids, but their individuality has yet to be established. *Aspertannic acid*, from the *Asperula odorata*, or

Woodruff; *Rubitannic acid*, from the leaves of the Madder plant; *Callutannic acid*, in the common Heather; *Rhodotannic acid*, in the Rhododendron leaf; *Leditannic acid*, in the wild Rosemary; and *Pinitannic acid*, in the bark of various Pines. *Gallerythronic acid* has been referred to this article on tannic acids; it is, however, a derivative of gallic acid, and is the cause of the deep blue coloration imparted to an aqueous solution of gallic acid, containing bicarbonate of lime, on exposure to the air: acids change it to red, but lime restores its blue colour.

Estimation of tannic acids. The amount of actual tanning material contained in a bark, &c., is often required to be known by the tanner. At present the only practical means of doing this, is to add a standard solution of gelatin to the decoction of a small quantity (10 to 50 grains) of the tanning substance until no further precipitate of tannate of gelatin is thrown down. The solution of gelatin is standardised by a known quantity of pure gallotannic acid; the amount of it required to precipitate the acid in the specimen under examination, is supposed to indicate the tanning value of that sample. It is a question, however, whether gelatin in solution precipitates the whole of the matters that skin does in the tan-pit; if it does, the process may be relied on, and it is certainly fair to assume that it does, inasmuch as skin is nearly all gelatinoid matter.

The following table indicates the amount of tannic acid in the chief varieties of tanning material. Not only do different substances differ much in the quantity they contain, but the same plant is much influenced by climate, soil, and age.

	Per cent.	Authority.
Oak bark, 100 years old	8·45	G. Muller.
,, young	13·87	Mulligan and Dowling.
,, British, 50 years old	8·90	
,, ,, about 50 years old	9·76	
,, ,, ,, 70 years old	6·12	
,, Southampton, 50 years	8·80	
,, coppice, picked	12·35	
,, Belgian	8·34	
,, ,, heavy	10·74	
,, ,, light	8·52	
,, an old specimen	9·00	Fehling.
,, best	19·00 to 21·00	
Gall nuts	30·00 to 33·00	
Aleppo galls	60·00 to 66·00	
Chinese galls	70·00	
White inner bark of old oak	21·00	Gassincourt.
,, ,, ,,	14·20	Sir H. Davy.
Oak, young	15·20	
,, middle bark	4·00	
,, spring cut	22·00	
,, the entire bark	6·00	
Willow bark, Leicester, white inner	16·00	
,, ,, middle	3·10	
,, ,, entire bark	6·80	
,,	3·95	Mulligan and Dowling.
,, weeping	16·40	Gassincourt.
Esehurgh oak bark	19·35	G. Muller.
Mimosa or Wattell bark	31·16	
,, ,,	17·97	Mulligan and Dowling.
Larch bark	1·60	Sir H. Davy.
,,	3·51	Mulligan and Dowling.
Cork-tree bark	12·16	
Hemlock bark	13·92	
Smyrna valonia	34·78	
Myrobalans	20·91	
Divi-divi	29·80	
,,	49·25	G. Muller.
Shumac	19·35	
,, Palermo	24·37	Mulligan and Dowling.
,, ,,	16·20	Sir H. Davy.
,, Malagra	10·40	Frank.
,, Carolina	5·00	Cadet de Gassincourt.
,, Virginian	10·00	
Catechu, Pegu, brown	46·88	Mulligan and Dowling.
,, Bombay, light	26·32	
,, ,, ,,	55·00	Sir H. Davy.
,, Bengal	44·00	

TANNIGENAMIC ACID. [TANNIC ACID.]

TANNIGENIC ACID. [TANNIC ACID.]

TANNIN. [TANNIC ACID.]

TANNIN, PURE, or TANNIC ACID, *Medical Properties of.* This substance in combination with extractive has been long known under the name of tannin, and recognised as the active principle in almost all astringent vegetables. [ASTRINGENTS.] As many of these are powerful in restraining excessive discharges, whether bloody or otherwise, it was conjectured that the pure principle would be yet more efficacious than when in a state of combination. Accordingly it has been administered in some passive hæmorrhages, chiefly from the uterus and the bronchial tubes. To effect any good it requires to be given for several days in small doses. It is with difficulty absorbed into the circulation, being with great reluctance taken up by the lacteals, and producing very great constipation, from its direct astringent action over the intestinal canal, with which it is brought into contact. Tannic acid has been recommended in cases of incurable organic diseases affecting the uterus, accompanied with wasting discharges. These it may for a time moderate, but the constipation induced never fails ultimately to aggravate the disease and discomfort of the patient. There is little therefore to induce practitioners to employ it to act on remote organs, as it appears to be converted into gallic acid wherever it is absorbed. To facilitate its action a solution of it in alcohol, or, better still, in ether is employed. This is a very powerful topical astringent. Tannin present in the after-math of grasses given as food for cattle seems to pass out almost unchanged, and in the quantity originally present. It is of use, along with the bitter extractive, in restraining the fermentation of the food. It is its presence in vegetables which causes the motions to become black when any preparation of iron or chalybeate water is taken.

TANNING. [LEATHER MANUFACTURE.]

TANTALUM. [COLUMBIUM.]

TANNOMELANIC ACID. [TANNIC ACID.]

TANNOXYLIC ACID. [TANNIC ACID.]

TAPESTRY (French, *Tapisserie;* Italian, *Tappezzeria*). This name is most commonly applied to the textile fabrics, usually composed of wool or silk, and sometimes enriched with gold and silver, woven or embroidered with figures, landscapes, or ornamental devices, and used as a lining or covering for the walls of apartments. It is derived from the French "tapis," which is from the Latin "tapetum," a carpet or covering for a bed or couch. The French "tapis," though generally applied to carpets, is also used to express other figured cloths used as coverings, such as the coverings of tables. Of the use of the word tapestry in this more extended sense, there is an instance in Shakspere's 'Comedy of Errors,' act iv., sc. 1.

Although the loom was employed from the earliest times by the Greeks and Romans for the production of ordinary tissues, its application to the weaving of ornamented or figured fabrics was chiefly Oriental. It is probable that many of the early tapestries were embroidered by hand or worked with the needle. This kind of work, of which the Bayeux tapestry is a celebrated example [BAYEUX TAPESTRY], was continued long after the practice of weaving tapestry in the loom had become common. The ornamented curtains of the Jewish tabernacle (Exodus, xxvi., xxxv., xxxvi.), are generally considered to have been embroidered by the needle.

Scanty as are the notices of tapestry in ancient writers, our information respecting it during the middle ages is not much fuller. Jubinal ('Recherches sur l'Usage et l'Origine des Tapisseries') observes that we find females engaged in working tapestry with the needle from the earliest epochs of the French monarchy. Gregory of Tours, writing towards the close of the 6th century, in his description of the rejoicings which followed the profession of Christianity by Clovis and his people, speaks of the streets being shaded with painted cloths or curtains (*velis depictis*), and the churches being adorned with hangings; and again, in describing the consecration of the church of St. Denis, he mentions tapestries embroidered with gold and garnished with pearls. The fabrication of tapestry hangings by the loom appears to have been introduced into France, at the earliest, about the 9th century, until which time the needle had been used exclusively in their production; and long after that period, the two processes were practised concurrently. At this time we often find embroidered cloths enumerated among the decorations of churches. From contemporary notices, it is evident that there was a celebrated manufacture of tapestry at Poitiers as early as 1025. Nor was the manufacture of tapestry confined to France at this period. The inhabitants of the north of Europe also practised it, and English embroidery was much admired and highly prized on the Continent. In the East also, where the art had been cultivated from the earliest antiquity, fine embroidery was produced in the 11th century. Much of the early Oriental tapestry was adorned with grotesque figures; and long after it became usual to depict natural figures and scenery upon tapestry, such devices were often used in ornamental borders.

In the 12th and 13th centuries the use of tapestry extended greatly. It passed from churches and monasteries, in which it had been used for curtains, palls, altar-cloths, vestments, &c., to the residences of the nobility. The use of tapestry in this way is believed by many writers on the subject to have been one of the luxuries introduced from the East in consequence of the increased intercourse occasioned by the crusades. The crusaders brought accounts of the Oriental practice of covering walls with prepared and ornamented skins, chiefly those of goats and sheep. These, which were probably at first used of their natural size and shape, were, at a later period, cut into rectangular pieces, about two feet high, and rather less in width, and united by sewing into very solid and handsome hangings, which were well adapted to resist damp. Such hangings, or leather tapestry, were manufactured much at Venice and Cordova, and were sometimes either gilt all over, or ornamented with gilt devices, in which case they bore the name of *d'or basané*. The Oriental origin of the more ordinary kind of tapestry is indicated by the name *Sarazins* or *Sarazinois*, which was frequently applied in France to the early manufacturers. In the following centuries tapestry was not only used to cover the interior walls, but was also employed on great occasions, as for instance on the public entries of princes, to decorate streets, and to impart a joyful appearance to towns and public places. It formed part of the decorations of festal halls, and was employed to ornament the galleries and other erections required at tournaments. Rich embroidery was also much employed in the decorations of the horses and men who formed the actors in those chivalric amusements; and the brilliant, though often grotesque devices of heraldry, which formed so important a part of the display upon such occasions, afforded extensive employment to the workers of tapestry and other ornamented tissues.

The art of making tapestry, for which the Flemings had been celebrated from the 12th century, made considerable progress in Flanders in the 14th century, and attained its highest perfection there in the 15th. Tapestry manufactories were early established at Brussels, Antwerp, Oudenarde, Lisle, Tournay, Bruges, and Valenciennes; but that of Arras was more celebrated than any other, and its productions were so highly prized, that the name *arras* became a common expression for the finest tapestry generally, whether made in that place or elsewhere. The hangings of Arras, as well as those of other manufactories in France, were for the most part executed in wool. Hemp and cotton were also used in them, but no silk or gold thread. The fabrication of tapestries formed of these substances was carried on chiefly at Florence and at Venice. The recollection of this difference is important in discovering where old tapestries were made. The designs included not only scenes from ancient history, from the fabulous stories of heroes, and from modern historical events; but hunts, fantastical animals, or the occupations peculiar to the different seasons of the year; while romantic and chivalric poems afforded a rich store of subjects for illustration. The 16th century, which was an age of general improvement in France, gave a new impulse to the production of tapestry. Francis I. founded the manufactures of Fontainebleau, in which threads of gold and silver were skilfully introduced into the work. It was, we are informed, with this new impulse that the practice was commenced of weaving tapestry in a single piece, instead of composing it, as before, of several smaller pieces joined together. This prince brought Primaticcio from Italy, and, among other works of art, commissioned him to make designs for several tapestries, which were woven at Fontainebleau. He also engaged Flemish workmen, whom he supplied with silk, wool, and other materials, and paid liberally for their labour. Henry II. established a manufacture of tapestry on the premises of the Hôpital de la Trinité, which attained its highest celebrity in the reign of Henry IV., and produced many fine tapestries. Henry IV. re-established, in 1597, the manufacture of tapestry at Paris, where it had been interrupted by the disorders of the preceding reigns. The establishment languished, if it did not become quite extinct, after the death of Henry IV.; but when the royal palaces, especially the Louvre and the Tuileries, were receiving their rich decorations, in the reign of Louis XIV., his minister Colbert revived it, and from that time the celebrated royal tapestry-manufactory of the Gobelins dates its origin.

The production of tapestry at the Gobelins is said to have attained the highest perfection in the time of the minister Colbert and his successor M. de Louvois. Le Brun, when chief director of the establishment, made many designs for working after; and M. de Louvois caused tapestry to be made from some of the finest designs of Raffaelle, Julio Romano, and other Italian painters. The manufacture declined greatly at the Revolution, but was revived under the government of Napoleon, and has ever since been carried on successfully, though not to the same extent as formerly. In England the art was practised from a very early date, the ladies of the Anglo-Saxon period being especially famous for their needle, and the Saxon chroniclers having frequent references to the rich hangings wrought by them. It was probably owing to the expense of such hangings, when of large size, and the very long time required for their production, that the less comfortable device of painting the walls of chambers was extensively adopted in the early Norman period.

Chaucer mentions a "tapiser," in company with a "webbe" and a "dyer," among his Canterbury pilgrims; from which circumstance it may be presumed that the business was not a very uncommon one towards the close of the 14th century. In the 15th century the use of tapestry greatly extended in England; but then, and for long after, the principal supply appears to have been from the Continent. In the 16th century a kind of hanging was introduced which holds a place intermediate between painted walls and woven or embroidered tapestry. Shakspere alludes to these hangings under the name of "painted cloths." See also the admirable description of the rich tapestry common in the Elizabethan period, by Spenser, in his 'Faërie Queene,' book iii., canto ix. The introduction of tapestry-weaving into England is usually attributed to a gentleman named Sheldon, late in the reign of Henry VIII., though it was known, if not commonly practised, much earlier. James I. endeavoured to revive the manufacture of tapestry, which had by his time considerably declined, by encouraging and assisting in the formation, about 1619, of an establishment at Mortlake, under the management of Sir Francis Crane. James I. gave 2000*l.* towards the formation of this establishment, which appears to have been originally supplied with designs from abroad, but subsequently by an artist named Francis Cleyne, or Klein, a native of Rostock, in the duchy of Mecklenburg, who was engaged for the purpose. This undertaking was a favourite hobby both with James and his successor, who regarded Cleyne so favourably that he bestowed upon him, in 1625, an annuity of 100*l.* (Rymer's 'Fœdera,' vol. xviii., p. 112), which he enjoyed until the civil war. In the same year Charles I. granted 2000*l.* a year for ten years to Sir Francis Crane, in lieu of an annual payment of 1000*l.* which he had previously covenanted to pay for that term, as the grant recites, "towards the furtherance, upholding, and maintenance of the worke of tapestries, latelie brought into this our kingdome by the said Sir Francis Crane, and now by him and his workmen practised and put in use at Mortlake, in our countie of Surrey;" and of a further sum of 6000*l.* due to the establishment for three suits of gold tapestries. ('Fœdera,' vol. xviii., p. 60.) After the death of Sir Francis Crane, his brother, Sir Richard, sold the premises to the king, and during the civil war they were seized as royal property. It was for the use of this establishment that Charles I. purchased the famous Cartoons of Raffaelle. [CARTOONS.] After the Restoration, Charles II. endeavoured to revive the manufacture, and employed Verrio to make designs for it, but the attempt was unsuccessful. During its period of prosperity, this manufacture produced superb hangings, after the designs of celebrated painters, with which the palaces of Windsor Castle, Hampton Court, Whitehall, St. James's, Nonsuch, Greenwich, &c., and many of the mansions of the nobility, were adorned. An act of parliament was passed in 1663 to encourage the linen and tapestry manufactures of England, and to restrain the great importation of foreign linen and tapestry.

In the primitive method of working tapestry with the needle, the wool was usually applied to a kind of canvas, and the effect produced was coarse and defective; but some finer kinds were embroidered upon a silken fabric. The process of weaving by the loom, after the manner known as the *haute lisse*, or high warp, was practised in the tapestries of Flanders (and according to Walpole and Jubinal, in those of England also), as early as the 14th and 15th centuries; the only essential difference between these and the productions of modern times being the comparative size of the pieces woven in the loom. The weaving of tapestry, both by the haute lisse and the basse lisse, appears to be of Oriental invention: the difference between the two methods may be thus briefly described. In the haute lisse the loom or frame with the warp-threads, is placed in a perpendicular position, and the weaver works standing; while in the basse lisse the frame with the warp is laid horizontally, and the weaver works in a sitting position. In weaving with the basse lisse, now seldom, if ever, employed, the design to be copied is laid beneath the threads of the warp, which are stretched in a manner resembling that of common weaving, the pattern being supported by a number of transverse threads stretched beneath it. The weaver, sitting before the loom, and leaning over the beam, carefully separates the threads of the warp with his fingers, so that he may see his pattern between them. He then takes in his other hand a kind of shuttle, called a *flûte*, charged with silk or wool of the colour required, and passes it between the threads, after separating them in the usual way by means of treddles worked by the feet. [WEAVING.] The thread of woof or shoot thus inserted is finally driven close up to the finished portion of the work by means of a reed or comb formed of box-wood or ivory, the teeth of which are inserted between the threads of the warp. In this process the face of the tapestry is downwards, so that the weaver cannot examine his work until the piece is completed and removed from the loom. The haute lisse loom, which is differently worked, consists of two upright side-pieces, with large rollers placed horizontally between them. The threads of the warp, which usually consist of twisted wool, are wound round the upper roller, and the finished web is coiled round the lower one. The design to be copied is placed perpendicularly behind the back or wrong side of the warp, and then the principal outlines of the pattern are drawn upon the front of the warp, the threads of which are sufficiently open to allow the artist to see the design between them. The cartoon is then removed so far back from the warp that the weaver may place himself between them with his back towards the former, so that he must turn round whenever he wishes to look at it. Attached to the upright side pieces of the frame are contrivances for separating the threads of the warp, so as to allow the *flûte*, or broach, which carries the woof, to pass between them. Like the weaver with the basse lisse, the operator works, as it were, blindfold; but by walking round to the front of the loom he may see the progress of his work, and may adjust any threads which have not been forced into their right position by the reed or comb, with a large needle, called an *aiguille à presser.* The process of working with the haute lisse is much slower than the other, and is, indeed, almost as slow as that of working with the needle.

It may be desirable in this place to say a few words concerning two varieties of carpet and rug-work, which, though not really tapestry, bear a certain resemblance to it, and are termed *Patent Tapestry* and *Wool Mosaic.*

The Patent Tapestry and Velvet-Pile Carpet, invented by Mr. Alexander Whytock, of Edinburgh, was intended to supersede the ordinary Brussels carpeting, and has to some extent had that effect. The peculiarity of this manufacture lies in the unlimited number of shades and colours that can be introduced; insomuch that the most elaborately-coloured designs, with flowers and scrolls, can be executed. There is also a very considerable saving of worsted, as compared with the older processes. The appearance is nearly similar to that of Brussels carpet, but the manufacture is more simple, each thread being coloured separately, at spaces, with the various shades as they follow each other in the design. The means by which this process is accomplished is simple and beautiful; but much care is required in placing and arranging the threads, and putting them on the beam. There being a heavy preparatory outlay incurred, each pattern must have a large sale to defray the cost. In the article Carpet Manufacture, certain descriptive details will be met with, which will serve to show how parti-coloured warps may be introduced to produce some such effect as is here denoted; the exact apparatus and processes need not be described here.

The *Wool Mosaic*, patented and manufactured by Messrs. Crossley, of Halifax, is an exceedingly curious production, involving no weaving process whatever. It may be called a velvet tapestry effect, produced by mosaic means. Artistic designs are prepared for this, of a higher order than is usual in carpets and rugs. The design on paper is ruled over in small squares, like a Berlin pattern; the size of the squares having a definite relation to the thickness of the woollen threads to be used. This design is re-copied upon ruled paper by girls, each of whom executes a portion of about a foot square. These papers then go into the factory. Woollen threads have previously been dyed to an almost infinite variety of colours, tints, and shades; for sometimes there are as many as a hundred different varieties introduced in one rug. A woman, especially skilled in this art, selects from a classified list all the colours that will be needed, taking one thread for every single square throughout the pattern. These threads are then brought together by means of a very remarkable apparatus. Every thread is stretched out horizontally to a length of about 17 feet, and is kept tight by a pull or force of about 4 lbs. One square foot of rug-work consists of about 50,000 threads, corresponding to that number of squares in the paper pattern. The force applied to the whole thus amounts to 200,000 lbs.; and hence the iron frame-work requires to be very strong. Girls, under the supervision of the mistress, are employed to stretch these threads, guided in so doing by bars and perforated plates. Thus they continue until a dense mass of worsted has been arranged, 17 feet long, 1 foot broad, and 1 foot deep. An ordinary hearth-rug, 6 feet by 2, requires 12 of these masses to complete the pattern, or 600,000 threads in all; equal to 10,200,000 feet, or nearly 2000 miles of worsted thread. This enormous quantity is made up into about a thousand rugs, all exactly alike, in the following way. The masses are firmly bound up, and cut into portions of convenient length. They are then arranged with the 600,000 threads vertical, all according to the proper pattern. A slice is cut off from the top, to render the upper surface quite level, by means of a large circular cutter revolving horizontally with great rapidity. The surface is coated with a hot solution of india rubber and camphine, then dried, then coated again, and so on two or three times. A backing, formed of canvas, is laid on with a strong cement of caoutchouc solution; and a little rubbing or scraping makes it adhere very firmly to the worsted. The circular cutter then severs a layer $\frac{3}{16}$ of an inch in thickness, which, by further processes, becomes applicable as rug, carpet, hanging, curtain, or tapestry. The mass of threads is thus cut away about a thousand times, producing this number of repetitions of the pattern. Copies of elaborate pictures may thus be obtained. The process does not become commercially successful unless there is a large sale for each pattern.

TAPIO'CA, a farinaceous substance, prepared in South America from two species of Janipha, *Manihot utilissima*, or the bitter, and *Manihot Aipi*, the sweet, Cassada or Manioc plants. The chief distinction between them is that a "tough ligneous fibre or cord runs through the heart of the sweet Cassava root, of which the bitter is destitute." Though the bitter contains a highly acrid and poisonous juice, from which the sweet is exempt, yet the bitter is cultivated almost to the entire exclusion of the other, which is probably owing to the greater facility with which it can be ground or rasped into flour, owing to the absence of the ligneous centre. The poisonous principle of the bitter manioc is thought to be of the nature of hydrocyanic acid. It is easily dissipated or decomposed by heat or fermentation; hence the flour becomes perfectly wholesome in the process of baking the cassava bread. The juice, after expression, may be inspissated by long boiling, or formed into a soup, with flesh and spices, called cassarepo, said to be powerfully antiseptic. By means of molasses it can be fermented and converted into intoxicating drink.

The fecula, or flour, after the juice has been carefully expressed, having been washed, and dried in the air without heat, is termed *mouchaco* in Brazil, *moussache* in the Antilles, and *cypipa* in Cayenne. This constitutes the Brazilian arrow-root of English commerce. When this fecula is prepared by drying on hot plates, it becomes granular, and is called *tapioca*. It occurs in irregular lumps or grains, and is partially soluble in cold water. The granules, diffused through water, and examined by the microscope, are of great uniformity of size, and smaller than those of arrow-root from the Marantas. Tapioca is very nutritious and easy of digestion, being free from all stimulating qualities. It is therefore very necessary to distinguish it from an artificial tapioca made with gum and potato starch, which is in larger granules, whiter, more easily broken, and more soluble in cold water than the genuine.

TAPPING, or Paracentésis (in Surgery), is the operation usually employed for the removal of fluid from any of the serous cavities of the body in which it has collected in a dangerous quantity. It is accomplished by means of an instrument called a trocar, and a tube, or canula, in which it exactly fits. The trocar is of steel, cylindrical through the chief part of its length, and terminated by a three-sided pyramid which ends in a very sharp point. The canula being placed upon its shaft, the trocar is thrust into the cavity containing the fluid, and being then withdrawn through the canula, the latter is retained in the aperture till all the fluid is discharged. The diseases for which tapping is chiefly performed are ascites, hydrothorax, hydrocele, and, occasionally, hydrocephalus, and effusions of fluid on the pericardium.

TAR. To give a concise definition of this familiar substance is difficult inasmuch as it varies in colour, composition, and consistence, and is derived equally from the animal, vegetable, and mineral kingdoms. From the colourless oil-like Naphtha, on the one hand, to the hard, black, resin-like Bitumen, or pitch, on the other, we have mixtures of the two, containing more or less of either, and to which the term tar is applied.

Tar, then, is a coloured oleo-resin. Deposits of it are frequently met with in nature, rarely however, in large quantities. The most important basins of it are found in Burmah, especially at Rangoon. Wells, about sixty feet deep, are sunk in the soil, and from their walls oozes out the tar and collects at the bottom; it has a brownish green colour, a goose-grease consistence, and is a mixture of several well-defined matters that will be referred to presently. Names, other than tar, have been given to this naturally occurring oleo-resin. Thus, we have *rock-oil* or *petroleum, black naphtha, liquid pitch, liquid bitumen, fluid asphalt*, and *mineral tar*.

But the vegetable kingdom is also a source of tar; indeed, it is the most important one, and wood and coal are the members which yield it. In commerce we meet with wood-tar in barrels holding about thirty gallons. Under the name of *Stockholm tar* it is imported from Russia, Sweden, Norway, Denmark and other northern parts of Europe; while that from the States of the New World is distinguished as *American tar*. The wood, especially that of the root, of pines, is the kind most profitably used in the production of tar; and it is subjected to a crude yet effective process of destructive distillation. A large neatly-trimmed hole of conical shape is made in a bank, hill-side or other sloping ground, and into this is lowered a similarly shaped bundle of pine-billets. The wood being kindled the whole is covered with turf. Slow partial combustion now goes on, the resin naturally existing in the wood melts, is slightly decomposed and darkened in colour by the heat, and flowing down to the bottom of the hole is there received in an iron dish having a long tubular spout which conveys it a few feet through the ground to the mouth of the barrel; the latter being placed for its reception in a cavity some two or three yards lower down the slope.

Coal-tar has already been treated of in a separate article [Coal-tar.] In appearance and complexity of composition it much resembles mineral and wood tar.

Remembering the vegetable nature of coal, it is easy to conceive that the above-described varieties of tar have a common origin. The production of, first, wood, then coal, and finally mineral tar are possibly sequential operations in nature which are simply hastened by the restless energy of man when, in the rude Macedonian fashion he half burns wood in the forest, or submits coal to destructive distillation aided by all the appliances of refined modern ingenuity.

Animal tar has already been treated of [Bone-liquor.] It is chiefly used for lubricating machinery.

Pitch.—When tar is heated in retorts it partially volatilises. The first portions of the distillate constitute *crude naphtha turpentine* and impure *pyroligneous* (acetic) *acid*, and next *oils* containing *paraffin* come over; the residue in the retort is *pitch*, a hard, black, vitreous resin.

Constituents of Tar.—By tedious processes of fractional distillation, each portion of the distillate being redistilled and its products collected in several separate quantities, and these again rectified and acted upon by powerful chemical reagents—coal-tar has been shown to consist of;—first, a number of very inflammable liquids, containing either the elements carbon and hydrogen only, as Cumole, Eupion, (from εὖ beautiful, and πίων fat) Toluole, and Xylole; or oxygen also, as in Kreasote, Capnomor (from καπνὸς, smoke, and μοῖρα part), and *picamar*. The latter is an oily body, of bitter taste, and specific gravity 1·10: it forms a crystalline compound with potash. The second series contains solid bodies, namely, Paraffin, Naphthalin Cedriret, (from *cedrium*, the old name for "acid tar-water," and *rete* a net, in allusion to the reticulated appearance of its crystals), Pyren, Chrysen, Pyroxanthin and *pittacal*; the latter has a deep blue colour, and is insoluble in water, alcohol, or ether. The liquid called *naphtha* chiefly consists of hydro-carbon; the *oils* contain the oxidised bodies; and *pitch* is a mixture of the various solids, together with other fixed matters that are probably decomposed when distillation is effected at very high temperatures, and which yield the charcoal that under these circumstances is always left in the retorts.

Mineral tar and coal-tar have been proved to consist of the same substances as wood-tar. As might be suspected, they contain less non-volatile matter than wood-tar.

Animal tar, besides the compounds already referred to, contains Methylamine, Ethylamine and other bases of the same class; Aniline and its homologues; and some nitriles of fatty acids.

TARANTISMUS is the name given to a peculiar nervous affection which was long supposed to be the consequence of the bite of the Tarantula Spider. It seems to have occurred frequently in the kingdom of Naples during the 16th century, and to have been nearly similar in its characters to the disease which was originally called St. Vitus's dance [CHOREA], and to that which has occasionally prevailed in parts of Scotland, and has been called the "leaping ague."

The patients, nearly all of whom were women, soon after being bitten (as it was supposed) used to fall into a profound stupor, from which nothing roused them but the sound of such music as pleased them, on hearing which they had an irresistible desire to dance. So long as the music continued, and was in tune and sufficiently lively, they would go on jumping and dancing till they fell exhausted; and, all the time, some used to shriek, some to laugh and sing, and some to weep. When, after a short rest, they had recovered from their fatigue, they would again begin to dance with as much vigour as before, unless the music were played slowly or confusedly, when they would stop and grow anxious and melancholy, or even, if the music were not soon made agreeable to them, would fall into a dangerous state of stupor. The disease used to last about four days, and seemed to be cured by the profuse perspirations brought on by the active exercise; but it often returned at the same time in the following year, or even for a succession of years, and on every occasion required the same treatment.

Since it has been found that the bite of the Tarantula can produce no such strange effects as these, many have suspected that the disease ascribed to it never really existed, but was feigned for the purpose of exciting pity or for the pleasure of dancing. There is good reason to believe that in most instances it was counterfeited: but there can be no doubt that such a disease had occurred and had given occasion to the practice of the fraud. Besides its similarity to diseases whose reality is generally admitted, such as the St. Vitus's dance and the leaping-ague, cases have occasionally been met with in recent times which closely resemble it, and in which there could be no just suspicion of fraud. Such a case is described by Mr. K. Wood, in the seventh volume of the 'Medico-Chirurgical Transactions;' another is recorded by Mr. Crichton, in the thirty-first volume of the 'Edinburgh Medical and Surgical Journal;' and in the 'Cyclopædia of Practical Medicine,' art. 'Chorea,' several cases of analogous affections are related. All these however occurred singly. That the Tarantismus and the St. Vitus's dance should have assumed the characters of epidemics may be ascribed to their propagating themselves, as all convulsive affections are apt to do among nervous and superstitious persons, by the propensity to imitation, the effects of which are still frequently seen in the production of hysteria, chorea, and similar diseases.

TARAXACIN. *Taxaracin.* A bitter non-azotised crystalline principle contained in the milky juice of the common dandelion. (*Leontodon Taraxacum.*)

TARE. We hardly know whether *all* the words *tare, tret, cloff, suttle, gross, net,* are still used in commerce; they all hold their places in works of arithmetic. *Tare* is said to be the allowance for the weight of the box or bag in which goods are packed; *tret,* an allowance of 4 lb. in 104 lb. for waste; *cloff,* an allowance of 2 lb. in 3 cwt., that the weight may hold good when sold by retail; the *gross* weight, that of the goods and package all together; the *suttle* weight, that which remains when tare only is allowed; the *net* weight, that which remains when all allowances are made. We shall merely state what we know of these words.

Tare (written *tara* in some of our older arithmetical works) is made from the Italian *tarare,* to abate. In that language *tara* is a technical term implying abatement of any kind, not for weight of package only. We believe *cloff* to have been the English word which originally stood for the allowance for package: in our older arithmeticians, tare and cloffe generally go together, and the latter seems to be for the package, the former for other abatements. *Cloff* or *clough* is defined in an old dictionary as that wherein any thing is put for carriage sake. Humphrey Baker (1562) speaks only of tare and cloffe; Masterson (1592), of tara, cloffe, and tret, but the first two terms are used together. We cannot find cloff used in the sense given to it by our modern books of arithmetic until about the end of the 17th century.

Tret seems to be from the Italian *tritare,* to crumble. Stevinus, in his Latin treatise on book-keeping, uses *intertrimentum* in the sense of deduction from the quantity charged for. *Gross* weight needs no explanation; the Italian form *netto* was formerly used for net weight. It being well known that these terms generally come to us from the Italian, we must suppose suttle to be from *sottile,* which is used in the sense of fine and valuable, and is applied to the finer part, as separated from the coarser. One of our old writers (Masterson, 'Arithmetike,' 1592) uses suttle weight in a manner which makes us imagine we see the origin of the *hundred* weight being a hundred *and twelve* pounds. Without any explanation, as if it were matter of notoriety, he contrasts *suttle* and *averdupois* weight, the former having 100 lbs. to the hundredweight, the latter 112 lbs. In the rougher sort of goods, at the same period, the tare was (as appears by the tables they give) very often 12 lbs. in 112 lbs.: perhaps then the hundredweight of 112 lbs. was only an allowance for the weight of the box, barrel, or other package.

TARES are a most important green crop in the improved systems of agriculture, especially on heavy soils, where they thrive best. When sown in autumn, with a small sprinkling of wheat or rye, they cover the ground in spring, and supply abundance of fodder in summer. A good crop of tares is fully equal in value to one of red clover: it comes off the ground in sufficient time to give the land a summer tillage, which is so useful in destroying weeds, and to allow turnips to be sown in the same season.

There are many species and varieties of tares; but that which is found the best adapted for agricultural purposes is the common tare (Vicia sativa), of which there are two principal varieties, very slightly differing in appearance, one of which is hardy, and will stand the severest winters: the other is more tender, and is therefore only sown in spring; but it has the advantage of vegetating more rapidly, so that spring tares sown in March will be fit to cut within a fortnight or three weeks after those which were sown in autumn. By sowing them at regular intervals from September to May, a succession of green tares in perfection, that is, in bloom, or when the pods are forming, may be cut for several months, from May to October. A prudent farmer arranges his crops so that he shall have artificial green food for his horses and cattle at least six months in the year, by having tares fit to cut between the first and second cut of clover. When there are more tares than is absolutely required for this purpose, and the weather permits, they make excellent hay; or, if the weather is not favourable, they are cut and given to sheep, which are folded on the portion already cut. It is an advantage to have portable racks for this purpose, that the fodder may not be trod under foot and wasted; or the tares may be placed between hurdles, tied two and two, which form extemporaneous racks. It is prudent to raise sufficient seed for another year; but a crop of seed-tares raised for sale is seldom profitable, as they greatly exhaust the soil: and the price varies so much in different seasons, that it becomes too much of a speculation for a farmer. The difference of spring and winter tares is probably more owing to habit than to any real botanical distinction between them. When spring tares are sown in autumn instead of winter tares, they may occasionally stand the frost, if not very severe; but, in general, they rot on the ground and never recover; whereas the real hardy winter tares, whose vegetation is slower, seem insensible to the severest frosts.

In the early part of summer green rye and tares, mixed, are sold at a great price in large towns for horses which have worked hard and been highly fed in winter. They act as a gentle laxative, and cool the blood: near London, where every produce is forced with an abundance of manure, tares are often fit to cut early in May, and the land is immediately ploughed and planted with potatoes, or sown with mangel wurzel or Swedish turnips, which come off in September or October, in time for wheat-sowing. Thus two very profitable crops are raised during the time that the land, according to the old system, would have been fallow; and at the same time it is left as clean, by careful hoeing, as the best fallow would have made it.

Tares should be sown on land which is well pulverised. If after wheat, the stubble should be ploughed in with a deep furrow after a powerful scarifier has gone over the land several times to loosen it: five or six cart-loads of good farm-yard dung should be ploughed in. The tares should be drilled or dibbled, and the surface well harrowed. The intervals should be hoed early in spring: this will accelerate the growth, and insure a complete covering of the ground. As soon as the tares show the flower, they may be cut daily till the pods are fully formed; after this, any which remain uncut should be made into hay or given to sheep; for if the seeds are allowed to swell, the ground will be much exhausted. Another piece should be ready to cut by this time, and thus there may be a succession of tares and broad clover from May to November. Tares may be sown as late as August, on a barley or rye stubble, for sheep-feed early in winter, or to be ploughed in to rot in the ground, where beans or peas are intended to be sown early in spring; this is perhaps the cheapest mode of manuring the land, the only expense being the seed; for the tillage is necessary at all events.

TARGUMS, or CHALDEE PARAPHRASES OF THE OLD TESTAMENT. During the Babylonish captivity, the language of the Jews was affected by the Chaldee dialect spoken at Babylon, to such an extent, that upon their return they could not understand the pure Hebrew of their sacred books; and therefore, when Ezra and the Levites read the law to the people, they found themselves obliged to add an explanation of it, undoubtedly in Chaldee. (Nehem. viii. 8.) [HEBREW LANGUAGE; ARAMÆAN LANGUAGE.] In course of time such explanations were committed to writing, and from their being not simple versions, but explanatory paraphrases, they were called by the Chaldee word *Targum,* which signifies "an explanation."

There are ten Targums extant:—

1. *The Targum of Onkelos,* on the Pentateuch, is the most ancient. Onkelos is supposed to have lived at Babylon. The Babylonish Talmud makes him a contemporary of Gamaliel, at the very beginning of the Christian era. No critics place him lower than the 2nd century. His language approaches nearer than that of the other Targums to the pure Chaldee of the books of Daniel and Ezra. He follows the Hebrew text so closely, that his work is less a paraphrase than a version, and he is free from the fables which prevailed among the later Jews.

2. *The Targum of Jonathan Ben Uzziel,* on the Prophets, is by many ascribed to an author contemporary with Onkelos, or even a little older, namely, Jonathan the son of Uzziel, a disciple of the elder Hillel. The mention of his name in the Talmuds proves him to have

lived earlier than the 4th and 5th centuries. But Jahn points out certain internal marks, from which he concludes that this Targum was compiled, towards the end of the 3rd century after Christ, from other paraphrases, some of which at least were considerably older. The Jews make Jonathan contemporary with the prophets Malachi, Zechariah, and Haggai, and relate marvellous stories respecting the composition of his Talmud. This Targum is more paraphrastic than that of Onkelos; its dialect is not so pure; the version is not so accurate, but it is free from the fabulous stories of the later Talmuds. It comprises the books of Joshua, Judges, Samuel, Kings, Isaiah, Jeremiah, Ezekiel, and the twelve minor prophets.

3. *The Targum of the pseudo-Jonathan*, on the Pentateuch, is so called from its having been erroneously ascribed to Jonathan Ben Uzziel. In purity of dialect, in its general style, and in its mode of exposition, it is far inferior to the Targum of Jonathan. It abounds in silly fables, and displays great ignorance of Hebrew on the part of its author. From internal evidence, such as its mention of the Turks and Lombards, it is evident that it could not have been written earlier than the 7th, or perhaps the 8th, century.

4. *The Jerusalem Targum*, on the Pentateuch, of which however it omits large portions, and sometimes explains only single words, is evidently later than that of the pseudo-Jonathan, which it generally follows closely, occasionally departing from it for the worse. Its dialect is very impure, abounding in Greek, Latin, and Persian words.

The other Targums scarcely deserve a separate notice. An account of them, and lists of the editions and Latin versions of the Targums, will be found in the works quoted at the end of this article. Taken together, the Targums form a paraphrase of the whole of the Old Testament, except the books of Daniel, Ezra, and Nehemiah, which called the less for such an exposition, as they are to a great extent written in Chaldee.

(Prideaux, *Connection*, part ii., book viii.; the *Introductions* of Horne and Jahn.)

TARIFF, a table of duties to be paid on goods imported or exported. The principle of a tariff depends upon the commercial policy of the body by which it is framed, and the details are constantly fluctuating with the change of interests and the wants of the community, or in pursuance of commercial treaties with other states. The British tariff has undergone many important alterations within the last sixty years, all tending to increased freedom of trade. Only twenty-six kinds of articles are now subject to an import duty, and none to an export duty, all being imposed merely for fiscal purposes. A tariff often aims at incompatible ends: duties are sometimes meant to be both productive of revenue and for protective objects, which are frequently inconsistent with each other. Hence they sometimes operate to the complete exclusion of foreign produce, and in so far no revenue can of course be received; and sometimes, when the duty is inordinately high, the amount of revenue becomes in consequence trifling. An attempt is in fact made to protect a great variety of particular interests at the expense of the revenue and of the commercial intercourse with other countries.

TARTAN. [WEAVING.]

TARTAR, CREAM OF. [TARTARIC ACID.]

TARTAR EMETIC. [ANTIMONY.]

TARTARIC ACID ($C_8H_4O_{10}, 2HO$). This acid occurs in nature in both the free and combined states. In the free condition it exists in the tamarind, grape, pine-apple, pepper, &c.; as a potash salt, also in the tamarind, grape, and in the mulberry; and as tartrate of lime, in the fruit of the stag's-horn sumach (*Rhus typhina*). Tartaric acid is also found in many other vegetable juices, but it is from the grape that nearly all the tartaric acid of commerce is obtained.

Bitartrate of potash is soluble in water, but not in alcohol; in a mixture of the two it is soluble to an extent dependant upon the proportion of the one to the other. When, therefore, the juice of the grape is fermented, there arrives a point at which the bitartrate of potash begins to crystallise out and deposit on the sides of the vessel in which it is contained, and this operation goes on until the whole of the sugar in the wine is converted into alcohol. In going out of solution it takes much colouring matter with it, and in this impure state is, at convenient seasons, removed and sent into commerce as *argol* or *crude tartar*. Purified by recrystallisation and treatment with animal charcoal, it constitutes purified tartar, or "*cream*" *of tartar;* and it is from this salt that tartaric acid is produced. "It is called *tartar*," says Paracelsus, "because it produces oil, water, tincture, and salt, which burn the patient as tartarus does." *Tartarus* is Latin for *hell*. The products of its destructive distillation are certainly somewhat irritating, and the properties of the "salt" (carbonate of potash) that is left are well known.

To prepare the acid, the bitartrate is dissolved in hot water, and powdered chalk added so long as effervescence continues. A precipitate of tartrate of lime is hereby formed, while neutral tartrate of potash remains in solution. The latter is then decomposed by adding the proper proportion of chloride of calcium, or by boiling with sulphate of lime. In either case the tartaric acid remaining in the potash salt is also thrown into the state of tartrate of lime. Finally, the tartrate of lime is gently heated with rather more than half its weight of strong sulphuric acid mixed with seven or eight times its weight of water. When the decomposition is complete the whole is filtered, the filtrate evaporated, if necessary, and the liquor set aside to crystallise.

Crystals of tartaric acid are colourless, inodorous, powerfully yet agreeably acid to the taste, of specific gravity 1·75, contain no water of crystallisation, and remain perfectly transparent and unaltered in the air. They are very soluble in water, alcohol, and wood spirit, but not in ether; the aqueous solution slowly decomposes if exposed. When gently warmed, they give evidence of being highly charged with electricity. Solution of tartaric acid, especially when hot, exerts a powerful twisting action on polarised rays of light. The direction of rotation is to the right, as observed in the apparatus described under SACCHARIMETRY: it is a remarkable phenomenon, and will presently be referred to as a means of distinguishing the derivatives and modifications of this acid from each other.

Tartaric acid gives a white precipitate (bitartrate of potash) when added in excess to a strong solution of a potash salt; it also throws down white tartrates from lime or baryta water and from acetate of lead, but does not decompose the chlorides of barium or calcium. Oxidising agents, such as peroxide of lead, red lead, bichromate of potash, nitric acid, &c., readily act upon tartaric acid and convert it into formic and carbonic acids. Fused with caustic potash, it splits up into acetic and oxalic acids, thus:—

$$\underbrace{2HO, C_8H_4O_{10}}_{\text{Tartaric acid.}} + \underbrace{3(KO, HO)}_{\substack{\text{Hydrate of}\\ \text{potash.}}} = \underbrace{KO, C_4H_3O_3}_{\substack{\text{Acetate of}\\ \text{potash.}}} + \underbrace{2KO, C_4O_6}_{\substack{\text{Oxalate of}\\ \text{potash.}}} + \underbrace{6HO}_{\text{Water.}}$$

By heat, tartaric acid is transformed into several modifications. Exposed to a temperature not exceeding 340° Fahr., it fuses, and is altered to an acid that has the same composition and apparently the same constitution as the original acid, but forms salts which are more soluble in water. It has a gummy appearance, is very deliquescent, does not when in excess precipitate ammonia from its salts until after some time, and then the crystals have a different form to that of ordinary bitartrate of ammonia. The solutions of its salts change into those of ordinary tartrates when boiled. The above is distinguished from the ordinary by the name *metatartaric acid*. By continued exposure to the same temperature, metatartaric acid is further modified to *isotartaric acid*, the chief peculiarity of which is that its salts correspond only to bitartrates. The formula ($HO, C_8H_5O_{11}$) probably therefore represents its true constitution. Closely associated with the above acids are the *tartralic* and *tartrelic:* they are formed on exposing tartaric acid to a still higher temperature for a shorter or longer period; they contain less water than the ordinary acid, and possibly are merely mixtures in different proportions of that substance with *anhydrous tartaric acid*, or *tartaric anhydride*. The latter body has the composition $C_8H_4O_{10}$: it always results when tartaric acid is maintained for some time at a temperature of 374° Fahr. It is insoluble in water, alcohol, or ether, and by long exposure in a moist state, or more rapidly on boiling in pure or alkaline water, is reconverted into the ordinary crystalline form of acid. Finally, on heating tartaric acid to 400° Fahr., and higher, in a distallatory apparatus, it is decomposed into carburetted hydrogen and carbonic acid gases, water, acetic acid, empyreumatic oily matters, pyruvic and pyrotartaric acids. *Pyruvic acid* ($2HO, C_{12}H_6O_{10}$) is separated from other matters in the distillate by fractional distillation and by taking advantage of the insolubility of its lead salt. Pyruvic acid is uncrystallisable, miscible in all proportions with water, alcohol, or ether, and forms difficultly crystallisable *pyruvates;* that of silver being somewhat soluble in water, and containing $2AgO, C_{12}H_6O_{10}$. *Pyrotartaric acid* ($2HO, C_{10}H_6O_6$) in the impure state remains as a syrupy liquid when the tartaric distillate above referred to is redistilled. It may be purified by distillation and exposure of its distillate in vacuo, when it separates out in crystals. The latter may be quite decolorised by solution in water, treatment with animal charcoal, and recrystallisation. Pyrotartaric acid crystallises in oblique prisms, is very soluble in water, alcohol, or ether, is volatile without decomposition, and forms well-defined crystalline salts with bases. It forms neutral and acid *pyrotartrates*, of the general formula $MO, HO, C_{10}H_6O_6$, or $2MO, C_{10}H_6O_6$. With persalts of iron it gives a red precipitate, and with protosalts a solution that rapidly reddens in contact with air.

Artificial Formation of Tartaric Acid.—This has been accomplished by Liebig. Its source is sugar of milk (lactose) and nitric acid is the oxidising agent. One part of lactose, two and a half of nitric acid, of sp. gr. 1·32, and an equal quantity of water, are gently heated; a mixture of carbonic acid and nitrogen oxides are disengaged and a separation of mucic acid takes place. Water is then added, the mixture filtered, half a part of nitric acid put into the liquid and the whole again boiled. More mucic acid—in all 33 per cent. of the lactose employed—then separates. After filtration a little more nitric acid is added, and the whole boiled for eighteen or twenty-four hours. On now neutralising the solution by potash, abundance of tartrate of potash is obtained, which may be purified by one or two crystallisations, and the acid isolated in the manner described at the commencement of this article.

The acid thus artificially obtained possesses all the properties of ordinary tartaric acid; it has dextro-rotative or plane polarised light, and is in fact identical with true tartaric acid. A short time since an announcement was made that tartaric acid had been artificially formed in another and totally different manner, but on optically examining it, the product proved to be racemic acid, a modified tartaric acid described farther on.

Tartrates.—Tartaric acid is bibasic, and its salts consequently are either acid ($MO, HO, C_8H_4O_{10}$) or neutral ($2MO, C_8H_4O_{10}$). The neutral salts may contain two similar or different protoxides; or a protoxide and a sesquioxide; or a protoxide and a teroxide. They are mostly formed by partially or wholly saturating the acid with the oxide or carbonate of the oxide; or, in the case of double tartrates, by saturating a bitartrate with an oxide different to that already contained in it. Heated in the air, tartrates blacken and give off an odour resembling that of burnt sugar. The chief tartrates are noticed in the following paragraph.

Tartrate of Ammonia ($2NH_4O, C_8H_4O_{10}$) is a very soluble salt; efflorescent, and losing ammonia when exposed to the air. *Bitartrate of ammonia,* ($NH_4O, HO, C_8H_4O_{10}$) is a crystalline powder tolerably soluble in hot water though but very slightly so in cold water. *Tartrate of potash* ($2KO, C_8H_4O_{10}$) crystallises with difficulty. *Bitartrate of potash* ($KO, HO, C_8H_4O_{10}$) was referred to at the commencement of this article: one part is soluble in 240 of water, at 50° Fahr. Heated to redness in a covered crucible it is decomposed, carbonate of potash and charcoal being left in a fine state of division; it constitutes the *black flux* of metallurgists. Sometimes it is deflagrated with nitre; in this the carbon is all oxidised, and *white flux* (carbonate of potash alone) is the name given to the residue. *Tartrate of soda* ($2NaO, C_8H_4O_{10} + 4$ aq.) resembles the corresponding potash salt. *Bitartrate of soda* ($NAO, HO, C_8H_4O_{10} + 2$ aq.) is far more soluble than bitartrate of potash. A solution of it—made by neutralising a given quantity by carbonate of soda, and then adding a second similar quantity of acid to the solution—forms, if it be saturated, a useful test of the presence of potash in a liquid, the bitartrate of the latter base being formed and precipitated if present in notable quantity. *Ammonio-tartrate of soda* contains ($NH_4O, NaO, C_8H_4O_{10} + 8$aq.) *Tartrate of potash and soda* ($KO, NaO, C_8H_4O_{10}$) is a laxative saline used in medicine. It is sometimes called sel de Leignette from the name of its discoverer who resided (1692) at Rochelle, hence also its name of Rochelle salt. In former times it was called *sal polychrest* (that is salt of many virtues). It is made by neutralising bitartrate of potash with carbonate of soda. *Tartrate of lime* ($2CaO, C_8H_4O_{10} + 8$aq) and bitartrate of lime ($CaO, HO, C_8H_4O_{10}$) occur native. *Tartrate of copper* ($2CuO, C_8H_4O_{10} + 6$ aq.) is a bright green crystalline powder. *Tartrate of ammonia and iron* ($NH_4O, Fe_2O_3, C_8H_4O_{10}, + 4$ to 5 aq.) and *Tartrate of potash and iron* ($KO, Fe_2O_3, C_8H_4O_{10}$) are used in medicine. They do not crystallise, but their solutions dry up when exposed on sheets of glass or other polished surfaces, and scale off in dark-red or brown laminæ. *Tartrate of potash and boron* ($KO, BO_3, C_8H_4O_{10}$ at 212° Fahr.) better known as *boro-tartrate of potash,* or *soluble cream of tartar,* is obtained on evaporating to dryness one part of boracic acid, two of bitartrate of potash, and twenty-four of water. *Tartrate of potash and antimony*, see ANTIMONY. A similar salt containing *arsenic* ($NH_4O, AsO_3, C_8H_4O_{10} +$ aq) may be obtained.

Racemic Acid ($2HO, C_8H_4O_{10} + 2$ aq.) *Paratartaric Acid.*—This isomeric modification is a frequent associate of tartaric acid, but it is in the grape of the Upper Rhine that it is abundantly met with. In all its relations it exhibits a close analogy to ordinary tartaric acid. The chief points of difference are:—that it crystallises more readily from solution: it contains two equivalents of water of crystallisation; it is less soluble in alcohol; it gives a precipitate with sulphate of lime, nitrate of lime, and chloride of calcium; and, finally, the racemate of lime is soluble in hydrochloric acid, and is precipitated unchanged on adding ammonia. By taking advantage of these properties, it may readily be distinguished and separated from tartaric acid. A point of considerable interest, connected with the constitution of racemic acid, is that its solution has no effect on a ray of plane polarised light. The *racemates* are very like the tartrates: racemate of lime is, however, considerably less soluble, and the double racemate of potash and antimony crystallises in acicular tufts instead of octohedra.

Artificial Formation of Racemic Acid.—Recently Messrs. Perkin and Duppa, and almost at the same time, Dr. Kekulé, have succeeded in producing paratartaric acid. It is formed when bibromosuccinate of silver is boiled in water, bromide of silver being precipitated:—

$$C_8H_2Br_2Ag_2O_8 + 4HO = 2HO, C_8H_4O_{10} + 2AgBr.$$

More recently M. Carlet, considering that lactose, which is dextrorotative, yielded, in the hand of Liebig, ordinary tartaric acid—concluded that dulcose (a saccharine principle imported from Madagascar) should by similar treatment furnish paratartaric acid. He tried the experiment and succeeded in producing a small quantity of racemic acid.

Constitution of Tartaric and Paratartaric Acid.—By the brilliant researches of M. Pasteur in this direction, chemistry has been put in possession of four kinds of tartaric acid. First, *dextro-tartaric acid,* or that which causes right-handed rotation of a ray of plane polarised light. This is the ordinary tartaric acid met with in commerce; it is sometimes, and, as will be seen directly, not inappropriately termed *dextro-racemic acid.* Second, *lævo-tartaric acid* which produces left-handed rotation, and which is also termed *lævo-racemic.* The crystals of these two acids differ in form in a somewhat interesting manner. Neither of them is ever obtained of a perfectly symmetrical shape, but what is remarkable is that the portion not forthcoming in the one is exactly the reverse of that wanting in the other. Moreover, the salts of the two acids preserve the peculiarities of the acids themselves; their rotatory power, chemical properties and appearance differing as the acids differ: thus the image, as seen in a mirror, of the crystal which is dextro-hemihedral, as its shape is termed, has the exact form of the lævo-hemihedral crystal; while the reflected image of the latter is of course identical with the direct image of the former. The third form of tartaric acid is a combination of the first with the second, and has, of course, no rotatory power: it is, in fact, racemic or paratartaric acid.

Racemic acid was, by M. Pasteur, made to yield up its respective constituents, dextro- and lævo-tartaric acid, in the following manner. The double racemate of soda and ammonia, made by saturating a quantity of common racemic acid with carbonate of soda, adding a second equal quantity of racemic acid, and finally neutralising by ammonia, was found to crystallise in opposite hemihedral forms. On picking out, by hand, the one variety from the other and optically examining their solutions, M. Pasteur found that each powerfully twisted a polarised ray, but in opposite directions. From the two salts the acids were isolated by first precipitating with nitrate of lead, then decomposing the washed lead salts by sulphuretted hydrogen, and lastly, allowing crystals to be deposited from the evaporated filtrates. The one set of crystals were found to be dextro-rotatory, the other lævo-rotatory; on adding equal quantities together, the original non-rotatory acid was obtained.

A second process for the separation of dextro-tartaric from lævo-tartaric acid has been discovered by M. Pasteur; it is not mechanical, like that of the separation from each other of the two kinds of crystals of racemate of soda and ammonia, but chemical, and depends upon principles which are generally applicable. It consists in combining racemic acid, or any other substance suspected of having an analogous binary constitution, with an active gyratory body. The necessary dissimilarity of properties in the compounds which such a body is capable of forming with the constituents of a complete substance will at once reveal whether the suspected body is complex or not. Thus, in preparing the racemate of cinchonicine, it always happens that when the liquid has attained a certain degree of concentration the first crop of crystals formed consists almost wholly of lævo-tartrate, the dextro-tartrate remaining in solution. A similar result is obtained with quinicine, except that dextro-tartrate first crystallises out, the lævo-tartrate remaining in the mother liquor.

The fourth kind of tartaric acid, discovered by the eminent chemist alluded to, is *inactive tartaric acid;* it has no action whatever on polarised light and, moreover, is not resolvable, under the same circumstances as is racemic acid, into dextro- and lævo-tartaric acids. It is formed as follows: tartrate of cinchonine is heated for several hours to 170° Fahr.; the mass is then treated with water and chloride of calcium added, when racemic acid, formed at the expense of the tartaric acid, is precipitated in the form of racemate of lime. If now the liquid be immediately filtered, and then left at rest for twenty-four hours, an additional crop of crystals is obtained, consisting of pure inactive tartrate of lime; from the latter the inactive acid itself is easily prepared.

Nitric derivatives of Tartaric Acid.—When tartaric acid is dissolved in nitric acid, and sulphuric acid added, a crystalline mass of *nitro-tartaric acid* is produced. It is very unstable and difficult to purify. Water decomposes it into *tartronic acid* ($C_6H_4O_{10}$).

The following derivatives of tartaric acid are prepared by the usual methods:—

Methyl-tartaric acid (tartromethylic acid)	$C_2H_3O, HO, C_8H_4O_{10}$
Tartrate of methyl	$2(C_2H_3O)C_8H_4O_{10}$
Ethyl-tartaric acid (tartrovinic acid)	$C_4H_5O, HO, C_8H_4O_{10}$
Tartrate of ethyl (tartaric ether)	$2(C_4H_5O)C_8H_4O_{10}$
Amyl-tartaric acid (tartramylic acid)	$C_{10}H_{11}O, HO, C_8H_4O_{10}$
Tartroglyceric acid	$C_6H_7O_5, HO, C_8H_4O_{10}$
Tartramic acid	$C_8H_7NO_{10}$
Tartramide	$C_8H_8N_2O_8$

Tartaric acid is much used in medicine; extensively also in the preparation of effervescing drinks, and, by the calico-printer and dyer.

TARTARIC ACID, for medical purposes, should be remarkably pure, when it is without odour, but makes a powerful acid impression on the organs of taste. In small doses, properly diluted, it acts as a refrigerant, and is of much value in fevers, particularly mucous, and in biliary remittents. It excites the appetite of persons in whom the stomach is in a healthy condition; and those who, by long indulgence in stimulating food and drinks, experience loss of appetite, painful digestion, constipation, with a yellow and altered countenance, and diminished muscular vigour, find in tartaric acid a remedy of singular power. For this state of system a few crystals should be dissolved in two small tumblers, and drank in the morning fasting, an hour intervening between the tumblers. A few grains are sufficient for each tumbler, as when made too strong it excites irritation, followed by purging. Occasionally it disturbs the nervous system in a distressing way, so that patients refuse to continue its use. This plan has in many instances reclaimed individuals addicted to habitual intoxication, to which they have recourse to relieve a painful feeling of sinking and craving of the stomach, which is effectually removed by the acid draught. This is also useful after an attack of *delirium tremens.*

Tartaric acid enters the circulation, and diffuses itself through the whole body, and may be recognised in the urine, generally in combination, often with lime. Tartaric acid is much used to decompose alkaline carbonates, and form effervescing draughts, the employment of which requires caution. [Antacids.]

TARTARUS (Τάρταρος) was, according to the notions of the Greeks and Romans, a part of the lower world, and was inaccessible to the light of the sun and to the winds. Homer describes it as the place in which the gods were punished; as being as far below Hades as heaven is above the earth, and as being provided with brazen gates at its entrance. ('Iliad,' viii. 13, &c., 481.) Hesiod entertains on the whole the same idea, but he adds that Tartarus is surrounded by a brazen wall and triple night; the roots of the earth and the sea hang down into it. It is the prison of the Titans. (Hesiod, 'Theog.,' 720, &c.) In later times Tartarus designated that part of the lower world in which the shades of the wicked were punished (Plato, 'De Re Publi.,' p. 616; Virgil, 'Æn.,' vi. 543), and the ideas then formed of it were more awful than in earlier times. According to Virgil, the road into the lower world was divided at a certain point into two roads, the left of which led into Tartarus, which was surrounded by a triple wall and the fiery river Phlegethon, and was closed with an adamantine gate. At its outer side Tisiphone kept watch, and at the inner side the fifty-headed hydra. Rhadamanthus was the judge in Tartarus, and at his command the Furies scourged the shades of the wicked.

TARTRALIC ACID. [Tartaric Acid.]

TARTRAMIC ACID. [Tartaric Acid.]

TARTRAMIDE. [Tartaric Acid.]

TARTRAMYLIC ACID. [Tartaric Acid.]

TARTROGLYCERIC ACID. [Tartaric Acid.]

TARTROMETHYLIC ACID. [Tartaric Acid.]

TARTRONIC ACID. [Tartaric Acid.]

TARTROVINIC ACID. [Tartaric Acid.]

TASTE, according to the definition of Sir Joshua Reynolds, "is that act of the mind by which we like or dislike, whatever be the subject." ('Discourses before the Royal Academy;' Discourse vii.)

Taste is frequently spoken of as a gift, as something independent of rules, a kind of instinct, bestowed more liberally in degree upon some men than upon others. It has been treated by some writers as the result of caprice or fashion, as having no uniform or permanent principles for the ground of its decisions. Others have resolved it into different complex elements, whose joint development is determined by certain principles of beauty or sublimity in things external.

Much obscurity has arisen in discussions on the subject of taste from the twofold sense in which the word taste has been employed, as expressive of an emotion, and of something objective in which there exists an aptitude to produce emotion. The term taste strictly applies to the emotion only; the theory of the different causes by which the emotion is produced belongs to the subject of beauty or sublimity. In what follows we shall confine ourselves to the explanation of taste in its restricted or proper sense.

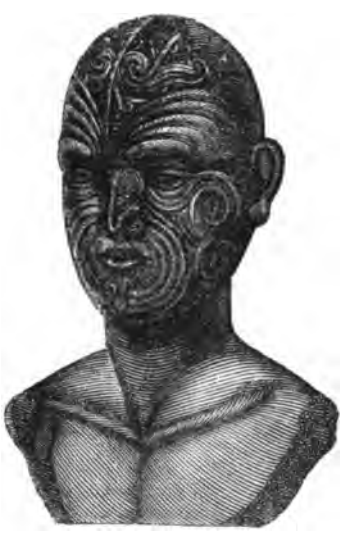
When any object either of sublimity or beauty is presented to the mind, we are conscious of a train of thought being immediately awakened analogous to the character or expression of the original object. The trains of thought which are thus suggested are distinguished in the nature of the ideas or conceptions which compose them, and in the nature or law of their succession. In the case of those trains of thought which are suggested by objects either of sublimity or beauty, they are in all cases composed of ideas capable of exciting some affection or emotion. There is this distinction between the emotions of taste and all our different emotions of simple pleasure, that in the case of these last emotions no additional train of thought is necessary. The pleasurable feeling follows immediately the presence of the object or quality, and has no dependence upon anything for its perfection but the sound state of the sense by which it is received. The emotions of envy, pity, benevolence, gratitude, utility, propriety, novelty, &c., might undoubtedly be felt, although we had no such power of mind as that by which we follow out a train of ideas, and certainly are felt in a thousand cases when this faculty is unemployed. In the case of the emotion of taste, on the other hand, it seems evident that this process of mind is necessary, and that unless it is produced these emotions are unfelt. Whatever may be the nature of that simple emotion which any object is fitted to excite, whether that of gaiety, tranquillity, melancholy, &c., if it produce not a train of kindred thought in our minds, we are conscious only of that simple emotion. Whenever, on the contrary, the train of thought which has been mentioned is produced we are conscious of a higher and more pleasing emotion; and which, though it is impossible to describe in language, we yet distinguish by the name of the emotion of taste. The emotions of taste may therefore be considered as distinguished from the emotions of simple pleasure, by their being dependent upon the exercise of our imagination.

It is on this principle that Burke remarks that the excellence and force of a composition must always be imperfectly estimated from its effect on the minds of any, except we know the temper and character of those minds. ('Int. to the Sublime and Beautiful.') The rules by which taste is determined vary with the objects to which its decisions refer; but in respect of all, this general principle holds, that a composition is to be judged by its fitness to produce the end designed by it. For a further discussion of the subject, see Æsthetics; Beauty; Sublimity.

TATTOOING is the name usually given to the custom, common among many uncivilised tribes, of marking the skin by punctures or incisions, and introducing into them coloured fluids, so as to produce an indelible stain. It is mentioned in Captain Cook's account of the South Sea islanders under the name *tattowing;* and, with trifling difference in the orthography, the same name is applied by English writers to similar practices among other people. The word "tattoo" appears to be formed by a reduplication of a Polynesian verb "ta," meaning to strike, and therefore to allude to the method of performing the operation, and, if this supposition be correct, it has a curious resemblance to the English word tattoo, meaning a particular beat of the drum.

From a passage in the book of Leviticus, chap. xix., v. 28, in which the Israelites are forbidden to make any cuttings in their flesh for the dead, or to *print any marks* upon their bodies, it has been supposed that some custom resembling tattooing was practised in the time of Moses. It is also an Oriental custom, and among people whose proximity to the Hebrews affords a reason for the prohibition contained in the text referred to. "The Bedouin Arabs, and those inhabitants of towns who are in any way allied to them," observes the editor of the 'Pictorial Bible,' on the passage in Leviticus, "are scarcely less fond of such decorations than any islanders of the Pacific Ocean. This is particularly the case among the females, who, in general, have their legs and arms, their front from the neck to the waist, and even their chins, lips, and other prominent parts of the face marked with blue stains in the form of flowers, circles, bands, stars, and various fanciful figures. They have no figures of living objects, such being forbidden by their religion; neither do they associate any superstitions with them, so far as we are able to ascertain." The works of ancient writers contain many notices of the practice of tattooing, as practised by several barbarous races. As to the Britons, Cæsar merely mentions their custom of staining their bodies with vitrum, or woad; but Solinus and Isidore describe a process exactly resembling the modern mode of tattooing. Herodotus says, that among the Thracians to be tattooed or marked (ἐστίχθαι) was an emblem of rank, and the want of it indicated meanness of descent (v. 6). The extended use of clothing at a later period rendered such ornaments superfluous, and led to the decline and subsequent abandonment of the practice. It appears, however, to have been continued during the whole of the Anglo-Saxon period, and is among the English vices reprobated by William of Malmesbury after the Norman conquest. Several other ancient notices on the subject are collected by Lafitau, in his 'Mœurs des Sauvages Amériquaines.'

In modern times the custom of tattooing has been found in most of the islands of the Pacific Ocean, and among many of the aboriginal tribes of Africa and America, as well as, on a limited scale, as before stated, in the East. It is also practised by the Tunguses on the banks of the Amur, as stated by Atkinson in his 'Travels in the Regions of the Upper and Lower Amoor.' Much curious information on the various kinds of tattooing is collected in the volume on the 'New Zealanders,' in the 'Library of Entertaining Knowledge.' Of the character of the



Head of Shungie, from a carving by himself.

patterns a better idea will be conveyed by the annexed bust of Shungie, a New Zealand chief, copied from an engraving in the 'Missionary Register' for 1816, than by the most lengthened description.

The process of tattooing as practised, or rather as it was formerly practised, in other islands of the South Sea, was less painful than that followed in New Zealand; for, according to the account of Captain Cook, in some cases the punctures could hardly be said to draw blood; while in New Zealand, having taken a piece of charcoal, and rubbed it upon a stone with a little water, so as to produce a thick liquid, the operators dipped into it an instrument made of bone, with a sharp edge like a chisel, and shaped in the fashion of a garden-hoe. They then applied the instrument to the skin, and struck it twice or thrice with a piece of wood, thereby making it cut into the flesh as a knife would have done, and causing a great deal of blood to flow, which they kept wiping off with the side of the hand, in order to see whether the impression was made sufficiently clear. If not, they applied the cutting-instrument again to the same place. The instruments used, as described by Captain Cook, were edged with small teeth, somewhat resembling those of a fine comb; and, as in the case of New Zealand, the colouring tincture was introduced at the same operation as that by which the skin was punctured; the substance employed in some places being a kind of lamp-black. On the brown skins of the natives, the marks made with this substance appear black; but on the skin of a European they are of a fine blue colour. Lafitau speaks of powdered charcoal as the colouring-matter commonly used by the American Indians; and states that it was introduced by a process subsequent to that of cutting or puncturing the skin. This insertion of the colour appears to have been the most painful part of the operation of tattooing as practised among them.

TAURIN ($C_4H_7NO_6S_2$), a peculiar crystallisable substance obtained from the bile, and also produced artificially by the action of heat upon isethionate of ammonia—

$$\underbrace{C_4H_5(NH_4)O_2, S_2O_6}_{\text{Isethionate of ammonia.}} = \underbrace{C_4H_7NO_6S_2}_{\text{Taurin.}} + 2HO$$

Its properties are, that it has the form of a six-sided prism terminated by pyramids of four or six faces; the crystals are gritty between the teeth, and have a sharpish taste, which is neither sweet nor saline; they undergo no alteration by exposure to the air even at 212°, and have neither an acid nor an alkaline reaction. When heated in the naked fire, this substance becomes brown, fuses into a thick liquid, swells up, exhales a sweetish empyreumatic odour resembling that of burning indigo, and leaves a charcoal, which is readily burnt: when submitted to dry distillation, it yields much thick brown oil, and a little yellow acidulous water, which holds an ammoniacal salt in solution, and reddens a solution of perchloride of iron; one part requires 15¼ parts of water at 54° for solution; it is much more soluble in boiling water, and the excess crystallises on cooling; it is but little soluble, even in boiling alcohol of sp. gr. 0·835, and is nearly insoluble in absolute alcohol. Concentrated sulphuric acid dissolves and forms a light brown solution with taurin; nitric acid readily dissolves it, and when the acid is evaporated, it is left unaltered.

TAUROCHOLALIC ACID. [CHOLEIC ACID.]

TAUROCHOLIC ACID. [CHOLEIC ACID.]

TAURUS (the Bull), the second constellation of the ZODIAC. Its position in the heavens, surrounded by Aries, Eridanus, Orion, and Perseus, is easily obtained by the manner in which its bright star ALDEBARAN is connected with the belt of Orion. In all speculations upon the origin of the Zodiac, Taurus must be an important object of consideration, since, at the earliest date which prudent speculation can consider it advisable to begin from, Aldebaran must have been at no great distance from the vernal equinox. [ZODIAC.] The figure is only a part of a bull—the head, shoulders, and fore legs. Aldebaran and the Hyades form the forehead and eye, and the Pleiades are in the shoulder. But Aratus must have drawn the figure differently, for he puts the Pleiades in the knees.

The Hyades form a group, of which five (some of the ancients said seven) are distinctly visible to the naked eye, α, θ, γ, δ, and ε of the constellation: there are many more in the cluster. These stars are arranged in the form of a V, α and ε being the extremes, and γ at the angular point. The star α is Aldebaran. The name seems to be derived from ὕειν, to rain. The Latins called them *suculæ* (little pigs, no doubt meaning Aldebaran for the sow, and the others for her offspring), a name which Cicero and others state to have arisen from supposing the Greek word to have been from ὕες (pigs), and not from ὕειν. We think, however, it may be possible that they were right in their idea of the Greek word: the large star and the cluster of small ones might very easily suggest the notion of a sow and her litter.

The Pleiades are so close a group of stars that it is very difficult to say how many are seen by the naked eye. "They are called seven," says Higinus, "but no one can see more than six;" and six seems to be the number generally visible, though there are many more in the cluster. These stars are 17, 19, 20, 23, 25, and 26 of Flamsteed. There is accordingly a supposition that some one star, once visible, has now changed its magnitude, or disappeared altogether. The name has been derived from πλεῖν, to sail. One of the mythological stories makes these stars the daughters of *Pleione* and Atlas.

The principal stars of Taurus are as follows:—

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
ο	1	1057	4
ξ	2	1068	4
η	25	1166	3
λ	35	1241	4
ν	38	1251	4
γ	54	1328	3
δ^1	61	1346	4
δ^2	64	1356	4–
ε	74	1376	4
α	87	1420	1
ι	102	1551	4
β	112	1681	2
ζ	123	1767	3

TAURUS PONIATOWSKI, a constellation formed by the Abbé Poczobut, a Polish astronomer (born in 1728: we do not know the year of his death; but Lalande mentions his having resumed his observations at Wilna in 1802), in honour of the reigning king of Poland, and adopted in the French (Fortin's) edition of Flamsteed's maps (or rather added to the plates). Poczobut, in 1778, proposed this constellation to the French and other academies, by whom it was received. Bode conjectures that a resemblance of certain very small stars in it to the figure of the Hyades was the reason for the first word of the name. It is situated between Aquila and Ophiuchus.

TAURYLIC ACID. [BENZOIC ALCOHOL.]

TAUTOCHRON. [TIME OF DESCENT.]

TAX, TAXATION. A tax is a portion of the produce of a country or its value, applied to public purposes by the government. Taxation is the general charging and levying of particular taxes upon the community.

In a free state it is assumed that all taxation is necessary for the public good; and it is justified by necessity alone. The amount of expenditure will, in a great measure, be determined by the magnitude of a state and by the number and importance of its political relations; yet the prudence with which its affairs are administered will affect the demands of the government upon the people nearly as much as its necessities. The expenses of a private person must be regulated by his income; but in a state, the expenditure that is needed is the measure of the public income that must be obtained to meet it. A civilised community requires not only protection from foreign enemies, and internal security, but it needs various institutions which are conducive to its welfare. It is the business of a government to provide for these objects in the best manner and at the least expense consistent with their efficiency. Every tax should be viewed as the purchase-money paid for equivalent advantages given in return. This principle assumes the necessity of moderation in levying taxes, and will scarcely be denied by any one when stated in that form; yet it is not uncommon to hear it argued that so long as taxes are *spent in the country*, the amount is not of consequence, as the money is returned through various channels to the people from whom it was derived. The principle we have just laid down exposes the fallacy of this doctrine, by reducing it to a simple question between debtor and creditor. For example, by paying a million of money every year, the people obtain the services of an army. This we will suppose to be an equivalent, and we will further assume that the food and clothing of the force are purchased, and that the entire pay of the men is spent, within the country. The whole of the money will thus be returned: but how? Not as a free gift, not as the repayment of a loan, but in the purchase of articles equal in value to the whole sum. The only benefit obtained by this return of the million is clearly nothing more than the ordinary profits of trade; for the community has already provided the money, and then out of its own capital and industry it produces what is equal to it in value, and this it *sells* to the state, receiving as payment the very sum it had itself contributed as a tax.

No branch of legislation is perhaps so important as the wise application of just principles in the matter of taxation. The wealth, happiness, and even the morals of the people are dependent upon the financial policy of their government.

Adam Smith lays down four general maxims, which are as follows:—

I. "The subjects of every state ought to contribute towards the support of the government as nearly as possible in proportion to their respective abilities; that is, in proportion to the revenue which they respectively enjoy under the protection of the state."

II. "The tax which each individual is bound to pay ought to be certain, and not arbitrary. The time of payment, the manner of payment, the quantity to be paid, ought all to be clear and plain to the contributor, and to every other person."

III. "Every tax ought to be levied at the time or in the manner most likely to be convenient for the contributor to pay it."

IV. "Every tax ought to be so contrived as both to take out and keep out of the pockets of the people as little as possible over and above what it brings into the public treasury of the state."

The justice of Adam Smith's first maxim requires no enforcement or illustration, although the object is most difficult of attainment. The second maxim is of great importance, and the necessity of adhering to it must be universally acknowledged. Uncertainty gives rise to frauds and extortion on the part of the tax-gatherer, and to ill-will and suspicion on that of the contributor, while it offers a most injurious impediment to all the operations of trade. Notwithstanding the many evils of uncertainty, it is by no means an uncommon fault in modern systems of taxation.

Under the constitutional governments of Europe, the people do not indeed suffer from violent exactions, as in the Turkish empire and in Persia; but industry and commerce are often restrained by irregular and ill-defined taxes.

To levy a tax "at the time and in the manner most likely to be convenient for the contributor to pay it" is always a wise policy on the part of the state. The time or manner of payment may often be more vexatious than the amount of the tax itself, and thus have the evil effects of high taxation, while it produces no revenue to the state. Suppose, for example, that a merchant imports goods and is required to pay a duty upon them immediately and before he has found a market for them:—he must either advance the money himself or borrow it from others, and in either case he will be obliged to charge the purchaser of the goods with the interest; or he must sell the goods at once, not on account of any commercial occasion for the sale, but in order to avoid prepayment of the tax. If he pays the tax and holds the goods, the consumer will have to repay not only the tax but the interest; and if he parts with them at a loss or inconvenience, trade is injured, and the general wealth and consequent productiveness of taxation proportionately diminished. To prevent these evils the Bonding or Warehouseing system was established in this country, which affords the most liberal convenience to the merchant and a general facility to trade. Certain warehouses are appointed under the charge of officers of the customs, in which goods may be deposited without being chargeable with duty until they are cleared for consumption, and thus the tax is paid when the article is wanted, and when it is least inconvenient to pay it. Similar accommodation is granted on their own premises to the manufacturers of articles liable to excise duties. At present the customs bonding-warehouses are confined to the ports, and a few large towns.

The evils resulting from inconvenient modes of assessing and collecting taxes have been very seriously felt in this country under the operation of the excise laws. When any manufacture is subject to excise duties, the officers of the revenue have cognisance of every part of the process, inspect and control the premises and machinery of the manufacturer, and often even prescribe the mode of conducting and the times of commencing and completing each process; while the observance of numberless minute regulations is enforced by severe penalties. The manufacturer is put to great inconvenience and expense, and his ingenuity and resources are constantly interfered with in such a manner as to impede inventions and improvements, and to diminish his profits. A London distiller stated to the Commissioners of Excise Inquiry, that assuming that the duties on spirits distilled by him should be fully secured to the revenue, "it would be well worth his while to pay 3000*l.* a-year for the privilege of exemption from excise interference." ('Digest of Reports of Commissioners of Excise Inquiry,' p. 15.)

Any injury done to trade is injurious to the state by diminishing the national wealth and the employment of labour. It has the same effect also upon the revenue as excessive taxation. The high price of the article limits the consumption and consequently the revenue arising from it. The injurious effects of the excise restrictions "must be felt in an accumulated degree by the public who are the consumers, against whom the tax operates by the addition made to the price of the commodity, not only by its direct amount, but by the necessity of compensating the manufacturer for his advance of capital in defraying it, and also by the increased cost of production." ('Ibid.,' p. 15.) In the case of a heavy tax, which also diminishes consumption, the state, at least, derives some benefit; but in the case of onerous restrictions and impediments to trade caused by the mode of collecting a tax, the state gains nothing whatever, and the manufacturer and the consumer are seriously injured, without an equivalent to any party. If the consumer must suffer, it should, at least, be for the benefit of the revenue, for then his contributions may be diminished in some other direction. During the last few years excise duties have been removed entirely from several manufactures, and in the instance of bricks and glass, especially in the latter, the improvements in the manufacture, and the remarkable diminution of price, have been of a most striking character, and produced the most beneficial effects.

The net produce of a tax is all that the state is interested in, and therefore any violation of the fourth maxim of Adam Smith is liable to the same objections as those already stated in reference to the third. Such violation increases the amount of the tax directly, as the former was shown to increase it indirectly, without any advantage to the state. Facility of collection is a great recommendation to any tax; and, on the contrary, a disproportion between the cost of collecting and the amount ultimately secured is a good ground for removing a tax, though founded in other respects upon just principles. On this account alone, as well as for the general convenience of trade, it has been a wise policy to reduce, as far as possible, the number of articles upon which customs duties are levied. The cost of collecting the duties upon the larger and more productive articles of import bears only a small proportion to the amount of the tax, while the expense of collecting the duties on the smaller and less productive articles bears a large proportion to the tax, and may in some cases exceed it.

Different Kinds of Taxes.—In selecting taxes for raising the revenue of a state, the principles already discussed should be adhered to as far as possible; but these do not point out any particular mode of taxation as preferable to others. Whatever mode of raising the necessary funds may be found to press most equally upon different members of the community, to be least liable to objections of uncertainty, or inconvenience in the mode or times of payment, or to be attended with the least expense, is fairly open to the choice of a statesman; unless objections of some other nature can be proved to outweigh these recommendations.

The two great divisions under which most taxes may be classed are *direct* and *indirect*.

Direct Taxes.—All taxes ought to be paid from the income of the community. To derive revenue from capital is to act the part of a spendthrift; and such a practice as, in private life, must be condemned. If the taxes of any country should become so disproportioned to its income, that, in order to pay them, continual demands must be made upon its capital, its resources would fail, employment of labour would decrease, and the revenue must necessarily be reduced by the general impoverishment of the tax-payers. Such a system could not long continue as regards all capital, but it may affect particular branches of capital, or all capital in certain conditions. In whatever degree it is permitted to operate, it is injurious. A tax upon legacies is a direct deduction from capital, and on that account objectionable, although it is profitable to the treasury, and very easily collected. [LEGACY; PROBATE.] The same observations apply to the probate duty, and to duties charged upon succession to the personal property of intestates.

With these exceptions, it has been the object of the British legislature to derive all taxes from income, either by direct assessment or by means of the voluntary expenditure of the people upon taxed commodities.

Direct taxes upon the land have been universally resorted to by all nations. In countries without commerce, land is the only source from which a revenue can be derived. In most of the Eastern monarchies the greater part of the revenue has usually been raised by heavy taxes upon the soil; and in Spain, at the present time, the taxes upon the soil are most oppressive and injurious.

In England, under the Saxon kings, there was a land-tax. When the invasions of the Danes became frequent, it was customary to purchase their forbearance by large sums of money; and, as the ordinary revenues of the crown were not sufficient, a tax was imposed on every hide of land in the kingdom. This tax seems to have been first imposed A.D. 991, and was called Danegeld, or Danish tax or tribute. [DANEGELD.] It was abolished about seventy years after the Norman Conquest, but a revenue still continued to be derived, under different names, from assessments upon all persons holding lands, which, however, became merged in the general subsidies introduced in the reigns of Richard II. and Henry IV. During the troubles in the reign of Charles I. and the Commonwealth, the practice of laying weekly and monthly assessments of specific sums upon the several counties was resorted to, and was found so profitable, that after the Restoration the ancient mode of granting subsidies was renewed on two occasions only. In 1692 a new valuation of estates was made, and certain payments were apportioned to each county and hundred, or other division. For upwards of a century the tax was payable under annual acts, and varied in amount from one shilling in the pound to four shillings, at which latter sum it was made perpetual by the 38 Geo. III., c. 60, subject, however, to redemption by the landowners upon certain conditions. But no new valuation of the land has been made, and the proportion chargeable to each district has continued the same as it was in the time of King William III., as regulated by the act of 1692. That assessment is said not to have been accurate even at that time, and of course improved cultivation and the application of capital have since completely changed the relative value of different portions of the soil. On account of the generally increased productiveness of land, the tax bears upon the whole a trifling proportion to the rent, yet its inequality is very great. Adam Smith imagined that this tax was borne entirely by the landlords, but this opinion has been proved to be erroneous by modern political economists, who hold that the tax increases the price of the produce of the land, and is therefore paid by the consumers. The tax is also obviously objectionable on the ground of inequality.

A tax upon the gross rent of land would fall upon the landlord, and would be in fact a tax upon his annual income, and as such would fall with undue severity upon him, unless other classes of the community should be liable to a proportionate deduction from their respective incomes for the benefit of the state. This brings us to consider the expediency of a general tax upon all incomes.

In whatever form the tax may be levied, the contribution should be paid from income, and not from capital; and, accordingly, the simplest and most equitable mode of taxation would appear to be that which, after assessing the annual income of each person arising from all sources, should take from him, directly, a certain proportion of his income as his share of the general contribution. Such a tax, equitably levied, would appear to agree in theory with all the four maxims of Adam Smith; but, practically, every tax upon income must abound in inequalities, in uncertainty, and in great personal hardships and inconvenience.

The strongest of the objections to an income-tax is, however, the inquisitorial nature of the investigation into the affairs of all men, which is necessary to secure a statement of their incomes. This objection, indeed, is treated lightly by some; but by the mass of the contributors it is considered the most inconvenient and unseasonable quality of an income-tax. Even if the exposure of a man's affairs could do him no possible injury, yet as an offence to his feelings, or even caprice, it is a hardship which is not involved in the payment of other taxes. But apart from matters of feeling, injury of a real character is also inflicted upon individuals by an exposure of their means and sources of income. Mercantile men, from the dread of competition, take pains to conceal from others, especially if in the same business, the application of their capital, the rate of profit realised, their connections, and their credit, all of which must be disclosed, perhaps to their serious injury, when there is an investigation of their profits.

For these reasons the mode of collecting the income-tax certainly cannot be approved of as being "most likely to be convenient to the contributor." Its general unpopularity when in operation is the best proof of its hardship and inconvenience. Upon the whole, a tax upon income is so difficult to adjust equitably to the means of individuals, and the mode of collection is necessarily liable to such strong objection, that, if resorted to at all, it should be reserved for extraordinary occasions of state necessity or danger, when ordinary sources of revenue cannot safely be relied on.

The English *Assessed taxes* have as few objections in principle as most modes of direct taxation. With an equitable assessment, and special exemptions in certain cases, they are capable of being made to bear a tolerably just proportion to the incomes of the individuals paying them. They share, however, in the general unpopularity of all direct taxes, and it cannot be denied that they often press unequally upon particular persons. The window-tax was indeed in many respects most objectionable, but it has happily been removed. The direct taxes upon horses, carriages, hair-powder, armorial bearings, &c., being paid voluntarily by the rich to gratify their own taste for luxury or display, are not likely to meet with many objectors. The use of such articles generally indicates the scale of income enjoyed by the contributor, and the tax is too light to discourage expenditure or to make any sensible deduction from his means.

Indirect Taxes.—In preferring one tax to another, a statesman may be influenced by political considerations as well as by strict views of financial expediency, and nothing is more likely to determine his choice than the probability of a cheerful acquiescence on the part of the people. All taxes are disliked, and the more directly and distinctly they are required to be paid, the more hateful they become. On this, as well as on other grounds, "indirect taxes," or taxes upon the consumption of various articles of merchandise, have been in favour with most governments. "Taxes upon merchandise," says Montesquieu, "are felt the least by the people, because no formal demand is made upon them. They can be so wisely contrived that the people shall scarcely know that they pay them. For this end it is of great consequence that the seller shall pay the tax. He knows well that he does not pay it for himself; and the buyer, who pays it in the end, confounds it with the price." ('Esprit des Lois,' livre xiii. chap. 7.) This effect of indirect taxes is apt to be undervalued by writers on political economy; but it is undoubtedly a great merit in any system of taxation (which is but a part of general government) that it should be popular, and not give rise to discontent. A tax that is positively injurious to the very parties who pay it without thought, is certainly not to be defended merely on the ground that no complaints are made of it; but it may be safely admitted as a principle, that of two taxes equally good in other respects, that is the best which is most acceptable to the people. The very facility, however, with which indirect taxes may be levied, makes it necessary to consider the incidents and effects of them with peculiar caution. The statesman has no warning, as in the cases of direct taxes, that evils are caused by an impost which is productive and which every one seems willing to pay. When any branch of industry is visibly declining, and its failure can be traced to no other cause than the discouraging pressure of a tax, the necessity of relief is felt at once; but if trade and manufactures are flourishing, and the country advancing in prosperity, it is difficult to detect the latent influence of taxes in restraining that progress, which but for them would have been greater; and still more difficult to imagine the new sources of wealth which might have been laid open if such taxes had not existed, or had been less heavy, or had been collected at different times or in different ways.

The government is directly interested in the increase of national wealth, and taxes upon commodities should be allowed to interfere with it as little as possible. On this account, duties upon raw materials are objectionable. They increase the price of such materials, and thus limit the power of the manufacturer to purchase them, and to employ labour in increasing their value, and in adding to the production and capital of the country. They discourage foreign commerce and the employment of shipping; for as the power of buying is restrained, so also is that of selling, and the interchange of merchandise between different countries is checked. Moreover, by increasing the price of the exported manufactures, they limit the demand for them abroad and subject them to dangerous competition.

Similar objections may be urged against taxes upon domestic manufactures, since by increasing the price they diminish consumption, and consequently discourage the manufactures, which if left to themselves would have given employment to more capital and labour, and would have added greatly to the amount of national wealth and prosperity. The object of a government should always be to collect its revenue from the results of successful employment of capital and industry, and not to press upon any intermediate stage of production.

The British legislature has of late years very wisely repealed or reduced various duties upon raw materials and upon manufactures. Of customs duties, none now remain but on articles of large consumption, such as tea, sugar, wine, tobacco, timber, &c., and all those upon raw material, and upon articles of small consumption, where the trouble and hindrance to the merchant exceeded the amount of income produced, have been repealed.

One of the chief recommendations of indirect taxes is, that, when placed upon the proper description of articles, the payment of them by the consumer is optional. If charged upon what may be strictly called the necessaries of life, their payment becomes compulsory, and falls with unequal weight upon labour. Competition generally reduces a large proportion of the working classes to a state which allows them little, if anything, beyond necessaries; consequently a duty upon these, as it will have no effect in diminishing the competition of labour and in raising wages, must reduce the comforts and stint the subsistence of labouring men.

That class of articles commonly called luxuries, of which the consumption is optional, is a fair subject of taxation. In principle there is no objection to such taxes: they do not interfere with industry or production, but are paid out of the incomes of the contributors, and paid willingly, and for the most part without undue pressure upon their means. But in laying on taxes upon particular articles of this description, care must be taken to proportion the charge to the value of the article. Excessive duties fail in the very object they have in view, by rendering the revenue less productive than moderate duties; while the causes of their failure are injurious to the wealth of the country by discouraging consumption, and to its morals by offering an inducement to smuggling.

High duties upon foreign articles imported into a country are liable to all the objections which apply to immoderate taxes upon articles of consumption, and they are chargeable with another—they diminish importation, and thereby restrict commercial intercourse and the demand for and exportation of domestic produce and manufactures.

The success of moderate duties upon articles of consumption, in encouraging the use of them, placing them within the reach of a larger number of persons, and at the same time augmenting the revenue, was never better shown than in the article of coffee. In 1824 the duty on British plantation coffee was 1*s.*, upon East India 1*s.* 6*d.*, and upon foreign coffee 2*s.* 6*d.* per lb., and the quantity cleared for consumption was 8,262,943 lbs., producing a net revenue of 420,988*l.* In 1825 those duties were reduced one-half, and the consequence was considerably more than a threefold increase in the consumption, while the revenue in 1841 had been more than doubled. The duty is now 3*d.* per lb., and the importation in 1859 was 65,358,029 lbs., of which 34,292,947 lbs. were entered for home consumption. There is no difference between foreign coffee and that of the production of British possessions.

Thus reductions of existing duties may be proved by such examples to increase the revenue; but whether the effect of them be immediate or deferred must depend upon a variety of circumstances. If the reduction puts an end to extensive smuggling, the revenue will derive immediate benefit, as both the demand and the supply of the article already exist; and the reduced tax, without affecting production or consumption, acts as a police regulation, and at once protects the revenue from fraud. But where there is little or no smuggling, and the revenue can only be increased by means of additional consumption, the effect of reduced duties may be deferred and even remote. The article may have to be produced; capital, skill, labour, and time may be required to provide it in sufficient quantities to meet the growing demands of the consumer; and even should the supply become abundant, the habits and tastes of a people cannot be changed on a sudden. The high price of an article may have placed it out of their reach, and in the meanwhile they may have become attached to a favourite substitute, or may be slow to spend their money upon a commodity which they have learned to do without. These and other causes may defer for a considerable time such an increase of consumption as would make up for the reduced rate of tax, especially when the reduction has been so great as to require an extraordinary addition to the previous amount of consumption, before the sacrifice made in the revenue can be redeemed. But where the article on which it is proposed to reduce a tax is already in universal request, and the supply immediate and abundant, and where the tax is so heavy as to restrain consumption, no present loss need be apprehended from a remission of part of the tax, and a very speedy increase of revenue may be expected. Sugar is an article of this description. It has become a necessary of life as well as a favourite luxury. There are scarcely any limits to the supply that could be raised, and the present duties add materially to the price and check consumption. As a proof of the suddenness with which the consumption of foreign sugar might be expected to increase if the excessive duty were reduced, we may refer to the effects of equalising the duties on East and West India sugars in 1836. In that year the duty on East India sugar was reduced from 32*s.* the cwt. to 24*s.* In 1835 the quantity imported had been 147,976 cwts.; and in 1837, one year only after the change, the import had increased to 302,945 cwts.; in 1838, to 474,100 cwts.; and in 1839, to 587,142 cwts. As the tax was diminished only by one-fourth, and the consumption was immediately more than doubled, the revenue at once gained considerably by the reduction of duty. The duty now varies from 18*s.* 4*d.* to 12*s.* 6*d.* per cwt., according to the quality, and the importation in 1859 was 7,426,791 cwts.; the quantity retained for home consumption was 8,847,119, on which the duty was 7,291,089*l.*, and the estimated value 12,516,757*l.*

A financial experiment will serve to show how little an increased revenue can be depended upon as the result of an augmentation of taxes upon articles of consumption. In 1840 an addition of 5 per cent. was made to all the duties of customs and excise, and a proportionate increase of revenue was anticipated, but not realised. The net produce of the customs and excise in the year ending January 5th, 1840, amounted to 37,911,506*l.* The estimated produce for the year ending January 5th, 1842, was 39,807,081*l.*, 1,895,575*l.* being expected from the additional 5 per cent. The actual increase, however, was only 206,715*l.*, or little more than ½ per cent. instead of the 5 per cent. which had been expected. This result was undoubtedly in part caused by a general stagnation of trade, and by the consequent distress which prevailed in that year; but we notice it because the principle of an indiscriminate augmentation of existing taxes, without reference to their present amount, character, and circumstances, is very unwise.

We have said that experience alone can show the precise rate of a particular tax which will not affect consumption and will at the same time discourage smuggling. It must be presumed that existing rates have been fixed in order to secure these results, and that they are justified by experience. To add to them, therefore, not because they are insufficient for their immediate object, but because a general addition to the revenue is needed, is to neglect experience and to disturb the proper relations between the amount of tax and the value of particular articles. During the last century it was a common financial course to add a general per centage of increase upon all the customs' duties whenever the revenue was found to be insufficient for immediate purposes. To this unwise policy must be attributed many of the strange anomalies which formerly existed in the British tariff. Any recurrence to so clumsy a mode of taxation should be avoided. The tax upon each article ought to be adjusted by itself upon sound principles, and then should not be changed merely to save the trouble or to avoid the unpopularity of selecting particular articles for increased taxation or of inventing new burdens.

Protective, Discriminating, and Prohibitory Duties.—The legitimate object of taxation is that of obtaining a revenue in the least injurious manner for the benefit of the community; but this object has constantly been overlooked for the sake of ends not fairly to be accomplished by taxation. Legislature should endeavour to encourage agriculture, trade, and manufactures; and it would be culpable to neglect any proper means of encouragement, which are not only beneficial to particular interests, but add to the general prosperity. Unfortunately, however, the zeal of most legislatures upon this point has been misdirected. They have seized upon taxation as the instrument of protection and encouragement; and, using it as such, have injured the great mass of their own countrymen, and ultimately have failed in promoting the very interests they had intended to serve. When the system of protection has existed, severe injuries and even injustice are inflicted whenever an attempt is made to undo the mischief which has been done. Reason and experience unite in teaching the impolicy of protective taxes; and, in our own country, this impolicy was acknowledged by the acts of 1846, which regulate the trade in grain, meal, and flour, and other articles.

The object of a protective duty is to raise artificially the price of the produce or manufactures of one country as compared with the produce or manufactures of another. A heavy tax easily effects this object, and thus prevents competition on the part of that country whose commodities are taxed, and establishes a monopoly in the supply of those commodities in favour of the parties for whose benefit the tax was imposed. The revenue, the avowed object of a tax, so far from being improved, is here actually sacrificed by the exclusion of merchandise, which at moderate duties would fill the coffers of the state. The state clearly is a loser; the foreigner, whose goods are denied a market, is a loser. Who then gains by these losses? Not the consumer; for the more abundant the supply, the better and cheaper will he find the market; but the seller, who is enabled to obtain a high price for his wares because he has a monopoly in the sale of them, is the only party who gains. The community at large suffer doubly: first, by having to buy dear instead of cheap goods, or by being denied the use of them altogether; and, secondly, by being obliged to pay other taxes which would not have been required if the very articles which would have made their purchases cheaper had been charged with a moderate impost. Even the sellers, for whom all these sacrifices are made, do not derive the benefit which might be expected. In the goods which they sell themselves, indeed, they are gainers; but in purchasing of other monopolists they lose by an artificially high price, like the rest of the community. It constantly happens too, that although the prices at which they sell are high, their profits are reduced, by the competition of others selling the same articles, to the general level of profits throughout the country. When this is the case, all parties, without exception, are losers—the state, the community, and the monopolists.

Protection may be accomplished by actual prohibition of the import of particular articles, by exorbitant duties which amount to prohibition, or by such duties only as give the home producer an advantage. Duties may also discriminate between the produce of different countries, and give the preference to some, to the injury and exclusion of others. In this country all these modes of protection have been resorted to: but their impolicy has been recognised by the legislature, which, within the last few years, has advanced rapidly in the adoption of a more sound system of taxation. [TARIFF.]

Duties are called discriminating or differential when they are not levied equally upon the produce or manufactures of different countries. The object of them is to give an advantage to the country on whose commodities the tax is lightest, as compared with others. To obtain such a preference has been the object of various negotiations and commercial treaties between different states, as it opens extensive markets to the industry of the favoured nation. By the commercial policy of England the principle of discrimination may be said to have been confined to the protection of our colonies against the competition of foreign countries. As regards each other, all foreign countries enjoy equal commercial advantages in their intercourse with England. It has been contended that colonies form an integral part of the mother-country, and that the commercial intercourse between the several parts of the British empire ought to be viewed as a vast coasting-trade, but now foreign vessels are admitted to this trade in England, although foreign nations refuse to adopt the like practice. If this principle were acted upon, it would certainly present a grand fiscal union worthy of admiration. There were two great articles of consumption, sugar and timber, upon which the discriminating duties have been most mischievous in their results. These discriminating duties have been abolished. Those on sugar have been noticed. Those on timber were reduced in 1847 and 1848, and in 1860 the difference between foreign and colonial timber was abolished, and 1*s.* per load only is imposed on all.

Export Duties.—Duties levied upon goods exported to foreign countries are ultimately paid by the foreign consumer, and thus have the effect of making the subject of one state bear the burdens of another. However desirable this may appear to the state, whose treasury is enriched at the expense of foreigners, the expediency of such duties will depend upon peculiar circumstances, and great nicety is required in the regulation of them. If a country possesses within itself some produce or manufacture much in request abroad, and for the production of which it has peculiar advantages, a moderate export duty may be very desirable. In this manner Russia, which almost alone supplies tallow to the rest of Europe, derives a considerable revenue from an export duty upon that article. Upon the same principle a duty upon machinery exported from Great Britain would have been politic. British machinists far excelled all others in skill and ingenuity, and foreign manufacturers were willing to pay almost any price for their machinery. Notwithstanding the prohibition, large quantities were smuggled abroad at an enormous cost, but the difficulty and expense of evasion were so great that foreigners had latterly almost confined their purchases, in this country, to models and drawings, and made the machinery themselves, with the assistance of British artisans, whom they enticed abroad by extravagant wages. The partial relaxation of the prohibitory law in 1825, by granting licences to export certain kinds of machinery, showed the extent to which the trade might have been carried under a more liberal policy. The official value of machinery exported under licence in 1840 was 593,064*l.*, in addition to various tools allowed by law to be exported, of which no account was taken. The restriction is now removed, and the declared value in 1859 amounted to 2,562,934*l.*

Though moderate export duties upon articles of which a country has almost the exclusive supply may be advisable, heavy duties will check the demand abroad in the same manner as they affect the consumption of commodities at home. In the same manner also they are injurious to trade and unprofitable to the revenue.

All duties, whatever, should be avoided upon the export of produce or manufactures which may be also sent from other countries to the same markets. They would discourage trade and offer a premium to foreign competition.

Although the temptation is great to shift taxes from one country to another by means of export duties, this temptation is equally great in all countries; and if their several governments should be actuated by the desire to make foreigners contribute to their revenue, their opportunities for carrying out such a system would probably be equal, and thus retaliations might be made upon each other, which, after all, would neutralise their efforts to tax foreigners, and leave them in the same position as if they had been contented to tax none but their own subjects. In this power of retaliation lies the antidote to the evil of one state being forced to bear the burdens of another as well as its own. Every state would naturally resist such an imposition upon its subjects, and export duties can therefore only be safely resorted to in such peculiar cases as we have noticed, where foreigners are willing to pay an increased price for commodities which they must have, and which they cannot obtain so good or so cheap from any other place.

TAXA'TIO ECCLESIA'STICA, signifies the assessment and levy of taxes upon the property of the church and of the clergy. The pope once claimed in all countries the first year's whole profits and the tenth part of the whole annual profits of every ecclesiastical benefice. These were called "First-Fruits and Tenths" [FIRST-FRUITS; TENTHS], and were, for the most part, paid willingly by the clergy to their ecclesiastical superior. The popes founded their claim upon scriptural precepts and practice, from the time of Melchizedek. The pope had his collectors in every diocese, who sometimes by bills of exchange, but generally in specie, yearly returned the tenths and first-fruits of the clergy to Rome.

But while the clergy were thus liable to taxation by their ecclesiastical head, it was maintained by the Roman Catholic church that their property enjoyed complete immunity against all claims of temporal powers, being set apart for the service of God, the support and dignity of the Christian church, and for works of charity. Upon this point frequent contests very naturally arose, and the vast possessions of the church tempted the pope and temporal princes by various modes to exact contributions from the clergy. The means resorted to by these respective powers to raise a revenue from the clergy, and the laws and customs that prevailed upon the matter, may be conveniently stated by dividing the subject into—

1. Taxation of the church or clergy by the pope for ecclesiastical purposes.

2. By temporal princes for the service of the state.

1. The pope was by no means satisfied with the regular contributions of the clergy, but continually applied to them for extraordinary funds for special purposes. In 1199, Pope Innocent III. issued a bull commanding the prelates and clergy of the Christian church to pay the fortieth part of all their revenues to defray the expenses of a crusade. This is said to have been the first attempt to impose a tax on the clergy of all nations by the authority of the pope as head of the church. The practice became frequent; and in 1225 the pope entertained a project by which the revenues of two prebends in every cathedral, and the portion of two monks in every monastery, in all the countries in communion with the Church of Rome, were to have been granted to the pope for the better support of his dignity. When this project was laid before the parliament of England in 1226, they evaded a direct answer to the papal legate, by alleging "that this affair concerned all Christendom; and that they would conform to the resolutions of other Christian countries." (Wilkin's 'Concilia,' vol. i.)

Two years afterwards, the king of England, Henry III., in order to induce the pope to interfere in a dispute concerning the appointment of an archbishop to the see of Canterbury, recently vacant by the death of Cardinal Langton, promised him a tenth of the moveables not only of the clergy but of the laity. In this proceeding there appears to have been a twofold peculiarity. First, a temporal prince offered the pope a contribution from his clergy, which commonly originated with the pope; and, secondly, a tax was to be levied upon the laity, not for the service of the state, but for the benefit of a foreign ecclesiastic. The strangeness of the circumstances, however, did not prevent the pope from taking immediate advantage of the king's offer, and he accordingly sent a legate into England to collect the tenths. His demand met with some opposition, chiefly from the barons, but the pope and the king together were too powerful to be resisted. In the same reign the pope's legates were constantly demanding presents from the bishops, monasteries, and clergy, and convening assemblies of the church, with no other object than to extort money. Their proceedings created such disgust that the great barons sent orders to the wardens of the seaports to stop all persons bringing any bulls or mandates from Rome, and at last succeeded in driving the legate himself out of the kingdom; but the sums which the pope continued to draw from the clergy at that time appear to have been enormous, and the histories of that period are full of complaints and remonstrances against papal exactions. An act was passed by the parliament in 1307 ('Statute of Carlisle,' 35 Edward I.) to restrain, in some measure, the exactions of the see of Rome, but apparently with little good results; for seventy years afterwards we find the Commons in parliament still protesting against the extortions of the pope. In their remonstrance to the king upon that grievance, they asserted "that the taxes paid to the pope yearly, out of England, amounted to five times as much as the taxes paid to the king." (Cotton's 'Abridgment.')

Although complaints continued long after this period, no measures were effectual in limiting the demands of the court of Rome until the pope's authority was altogether suppressed in England at the Reformation in the reign of Henry VIII.

2. The immunities claimed by the church were not effectual in protecting its revenues from being laid under contribution for the service of the state. The kings of England, sometimes by the pope's authority, sometimes by forced or voluntary compliance on the part of the church, and sometimes by their own direct power, obtained large sums from the clergy.

William the Conqueror found the church very wealthy, and subjected it to much spoliation. A singular occasion for taxing the clergy arose in the reign of Henry I., A.D. 1129. An ecclesiastical council, assembled at London, denounced all married clergymen, and decreed that they should put away their wives. The council committed to the king the execution of their decrees; but he, instead of compelling the clergy to send away their wives, imposed a tax on those who chose to retain them, which is said to have been very productive.

The pope was not unwilling to assist in oppressing the clergy for the benefit of kings, when they were inclined to further his own objects, either by undertaking crusades, carrying on wars against his enemies, or making concessions to him. He would not suffer the immunities of the church to be infringed by the temporal power, but often placed at the disposal of princes the revenues of the church by his own authority. Thus, the pope, by virtue of his apostolical power, granted King Henry III., by several bulls, the goods of all clergymen who died intestate, the revenues of all vacant benefices, and of all non-residents. In 1288, Pope Nicholas IV. granted the tenths to King Edward I. for six years, towards defraying the expenses of an expedition to the Holy Land; and in order to collect them at their full value, a taxation by the king's precept was begun in that year, and finished, as to the province of Canterbury, in 1291, and as to that of York in the following year, the whole being under the direction of the bishops of Winchester and Lincoln. This taxation is a most important record, because all the taxes of the church, as well to the kings of England as to the pope, were afterwards regulated by it until the survey made by Henry VIII.; and because the statutes of colleges which were founded before the Reformation are also interpreted by this criterion, according to which their benefices, under a certain value, are exempted from the restriction in the statute 21 Henry VIII. concerning pluralities. ('Preface to Taxatio Ecclesiastica, P. Nich. IV., by the Record Commissioners.')

In 1295, Edward, notwithstanding the pope's grant, and numerous exactions from the clergy in the meantime, being still in great need of money to carry on his wars, summoned deputies from the inferior clergy for the first time to vote him supplies from their own body. In the preceding year he had, by threats and violence, exacted a tax of half the revenues of the clergy; but now he thought it prudent to obtain their consent to his demands in a more regular manner. The clergy, however, would not obey the king's writ of summons, lest they should appear to acknowledge the temporal power; and in order to overcome this objection, the king issued his writ to the archbishop, who, as their spiritual superior, summoned the clergy to meet in convocation. (Gilbert's 'History of the Exchequer.')

This was the commencement of the constitutional practice of the clergy meeting in Convocation at the same time as the Lay Parliament, and voting subsidies by its own voluntary act for the service of the state. It was not viewed without alarm by the pope and the high church dignitaries; and in order to put a stop to all such exactions of princes from the clergy, Pope Boniface VIII. issued a bull in 1296, which forbade churchmen of every degree to pay any tribute, subsidy, or gift to laymen, without authority from the see of Rome; and declared that if they should pay, or princes exact, or any one assist in levying such unauthorised taxes, all such persons respectively would incur the sentence of excommunication. (Rymer's 'Fœdera,' vol. i., part 2.)

In the same year, however, Edward I. demanded of the clergy a fifth of their moveables, which they resisted, on the ground that they could not disobey the pope; but the king was not inclined to desist; and in order to force the acquiescence of the clergy, he put them out of the pale of the laws. Orders were issued to the judges to hear no cause brought before them by the clergy, but to decide all causes in which they were sued by others. The clergy could not long resist these oppressions; and although unwilling to disobey the papal bull, they evaded it by voluntarily depositing a sum equivalent to the amount demanded of them in some church, whence it was taken by the king's officers. In this expedient the whole ecclesiastical body acquiesced, and thus yielded up their spiritual privileges, under coercion by the temporal power.

At the Reformation, the chief source of revenue to the pope, namely, first-fruits and tenths, was transferred to the king "for more augmentation and maintenance of the royal estate of his imperial crown and dignity of supreme head of the Church of England." (Stat. 26 Henry VIII., c. 3.) In order to collect this revenue, a court of first-fruits was established, and the king ordered a valuation to be made of all the episcopal sees and benefices in England. The book which contains this valuation is called the 'Liber Regis.' The first-fruits and tenths continued to form part of the royal revenue until Queen Anne, by the Act 2 & 3 of her reign, c. 11, gave up the proceeds thereof on the part of herself and her successors, and assigned them for ever to the augmentation of poor livings.

It now only remains to notice more particularly the practice of taxing the clergy in convocation, which continued in full force till the reign of Charles II. It had afforded the kings of England a lucrative revenue from the church. Their influence as heads of the church, and as having ecclesiastical preferments to bestow, was very great after the

Reformation, and enabled them very commonly to obtain larger subsidies from the convocation than those that were voted by parliament. The church, therefore, was not unwilling to be deprived of the expensive privilege of voting separate subsidies; and acquiesced in an arrangement proposed in 1664–5, by which the Commons have ever since voted taxes upon the possessions of the church and of the clergy, in the same manner as upon the laity.

TAXES. The general objects, character, and principles of taxation and of different classes of taxes, are treated of under the head of TAX, TAXATION. In this place it is proposed to give a short summary of the amount and description of taxes paid in Great Britain and Ireland, whether assessed directly upon property, or collected indirectly upon articles of consumption; including not only such taxes as are paid to the general government, but also all municipal and local assessments or contributions.

United Kingdom.

The chief sources of revenue will be seen by the following statement, made up to December 31, 1860.

	Gross Receipts.
Customs	£23,032,395
Excise	19,069,000
Stamps	8,285,258
Taxes (land and assessed)	3,126,000
Property tax	12,901,816
Post Office	3,420,000
Crown lands	289,568
Miscellaneous	1,843,457
Total revenue	£71,967,494

From which the salaries, &c. of the revenue departments, amounting to 4,509,402*l.* has to be deducted as the charge for collecting; of this, the Post Office expenses for management in 1859 was 1,851,953*l.* The remainder, 2,657,449*l.*, gives an average of less than 9*d.* in the pound as the charge of collection.

The assessed taxes are the house-tax, the tax on male servants, taxes on carriages, on horses, on dogs, armorial bearings, horse-dealers' duty, game duties, stage-coach duties, and duties on passengers conveyed for hire by carriages travelling on railways. In 1840 (3 & 4 Vict. c. 17) 10 per cent. additional was imposed on all the assessed taxes. The income-tax was imposed April 5th, 1842, for three years, and was then renewed for another three years, and has been continued at varied intervals ever since. For 1860 it was imposed at 10*d.* in the pound; for 1861–2 it is proposed to reduce it to 9*d.* in the pound.

Bachelors, except Roman Catholic clergymen, pay an additional duty of 1*l.* on male servants. [BACHELOR.] The charges for game duties are stated under GAME LAWS. The duty on passengers conveyed for hire by carriages travelling on railways is 5 per cent. on the gross amount of the fares. As to the duties on stage-coaches, see STAGE-CARRIAGE.

To these parliamentary taxes may be added the following local assessments in England and Wales:—

	£
Poor-rates (which includes county, borough and police rates, 700,000*l.*)	8,188,880
Church-rates (average of seven years)	261,716
Additional voluntary contributions	269,550
Highway-rates	1,949,817
Turnpike-tolls (England and Wales)	1,031,050
Metropolitan local management	159,886

The rates levied for local management could not be ascertained, but including poors-rates in Scotland and Ireland, in the grand jury presentments in the latter country, the whole is estimated in a return, avowedly imperfect, laid before parliament, at 15,171,646*l.* in 1860.

The tithes of Great Britain and Ireland are said to amount to 4,000,000*l.*

There was published under the direction of the Poor-Law Commissioners in 1846, a valuable work entitled 'The Local Taxes of the United Kingdom, containing a Digest of the Law with a Summary of statistical Information concerning the Several Local Taxes in England, Scotland, and Ireland.' England includes England and Wales. It is remarked in the Introduction that "these Local Taxes are of two kinds: the rates raised in defined districts; and the tolls, dues, and fees paid for particular services or on certain occasions. But those rates only will be here noticed, which are authorised by general statutes or the common law; excluding such as derive their origin from special or local Acts." The rates are divided into three classes. I. Rates of independent districts, on the basis of the poor-rate. II. Rates of independent districts, not on the basis of the poor-rate. III. Rates of aggregate districts, on the basis of the poor-rate. No. I. comprehends —1, The Poor Rate. 2, The Workhouse Building Rate. 3, The Survey and Valuation Rate. 4, The Jail Fees' Rate. 5, The Constables' Rate. 6, The Highway Rates (three). 7, The Lighting and Watching Rate. 8, The Militia Rate. No. II. comprehends—1, The Church Rates (three). 2, The Sewer Rate. 3, The General Sewers' Tax. 4, The Drainage and Inclosure Rates. 5, The Inclosure Rate. 6, The Regulated Pasture Rate. No. III. comprehends—*Counties.* 1, The County Rate. 2, The Police Rate. 3, The Shire Hall Rate. 4, The Lunatic Asylum Rate. 5, The Burial Rate.—*Hundreds.* 6, The Hundred Rate.—*Boroughs.* 7, The Borough Rate. 8, The Watch Rate. 9, The Jail Rate. 10, The Prisoners' Rates. 11, The Lunatic Asylum Rate. 12, The Museum Rate.—*Counties and Boroughs.* 13, The District Prison Rates.

The Local Taxes in Scotland are distributed by Mr. Burton under the following heads:—

I. Administration of Justice, which includes Criminal Prosecutions, Court Rooms and County Buildings, Rural Police, Town Police, Prisons. II. Internal Transit, which includes Commutation Roads, Turnpike Roads, Highland Roads and Bridges. III. Navigation. IV. Civic Economy, which includes Direct Municipal Taxes, Petty Customs, Miscellaneous Burdens. V. Relief of the Poor. VI. The Church and Education, which includes The Church of Scotland Education. VII. Miscellaneous Taxes.

Mr. Burton observes "that the money expended on the ecclesiastical establishment and on education, partakes, in some respects, of the nature of a tax." The amount of money annually levied by local taxation in Scotland is not accurately known. The sum of 956,678*l.* is the approximate amount given by Mr. Burton.

The Local Rates levied in Ireland are distributed under the following heads in the work published under the direction of the Poor-Law Commissioners.

I. Grand Jury Cess (in all the counties, including counties of cities and towns).
II. Poor-Rates (in 130 Unions, comprising every townland and denomination of land in Ireland).
III. Lighting, Cleansing, and Watching Rates (in all cities, towns, and boroughs which may adopt the provisions of the statute).
IV. Borough Rates (in certain Boroughs).
V. Pipe Water Rates (in every city and town, except Dublin, Cork, and Limerick, which gives title to a bishop or archbishop).
VI. Parish Cess (in all parishes, unions of parishes, or chapelries in Ireland).
VII. Rates for deserted children (in all parishes in Ireland, except those in the city of Cork).
VIII. Ministers' Money (in cities and towns corporate in Ireland).
IX. Board of Health Rates (in parishes in which the lord lieutenant shall direct officers of health to be appointed).

"Besides the above rates leviable under general acts of parliament, there are rates leviable under special acts in many places, as Dublin, Cork," &c.

Information about the several taxes of European States will be found in the Parliamentary Paper, No. 227, of 1842, ordered by the House of Commons to be printed, 3rd May, 1842.

TAYLOR'S THEOREM. We propose in this part of the article to give some results of the methods of algebraical development which are consequences of the celebrated theorem, the history of which is given in the article TAYLOR, BROOK, in BIOG. DIV. The simplest parts of the Differential and Integral Calculus will be presumed known. It is not usual in works on that subject to bring together in one place the most conspicuous theorems which have arisen out of that of Taylor; which makes it the more desirable that such a thing should be done in a work of reference. It is to be particularly remembered that we do not here profess to teach the subject of development, but only to recall the steps of the several processes to those who have already learnt them, and to present the theorems in a form which can be easily referred to.

As to notation, we shall frequently signify differentiation by accents: thus $\phi''x$ is the second differential coefficient of ϕx with respect to x; $(\phi x \psi x)'''$ is the third differential coefficient of the product of ϕx and ψx. And $[n]$ will signify the product $1 \times 2 \times 3 \times \ldots . \times (n-1) \times n$. Moreover, when a series is written, three terms will be written down, and the general term appended.

Taylor's theorem is as follows:—

$$\phi(x+h) = \phi x + \phi' x \,.\, h + \phi'' x \frac{h^2}{2} + \text{\&c.} \quad \left\{ \phi^{(n)} x \frac{h^n}{[n]} \right\}$$

This theorem is true whenever x has such a value that—1. No one of the set ϕx, $\phi' x$, &c. is infinite. 2. All of them do not vanish. Thus neither of the following could be allowed to be treated by it when $x = a$:—

$$\sqrt{(x^2 - a^2)} \,.\, \log x \quad \text{and} \quad \epsilon^{-(x-a)^{-1}}.$$

In the first function, $\phi' x$, and all which follow, are infinite when $x = a$; in the second ϕx and all its differential coefficients vanish when $x = a$. The meaning of this circumstance is as follows: the form of Taylor's theorem essentially requires that $\phi(x+h)$ should be developed in ascending integer powers of h; consequently when such form of development is impossible, this theorem may show signs of being inapplicable. Now, the first of these functions (when $x = a$) can only have $\phi(a+h)$ expanded in ascending fractional powers; and the second only in descending integer powers. Those who will only allow the use of converging series may require also that h should be so small that the resulting series is convergent: but this Cauchy has proved always happens if h be small enough.

In the Penny Cyclopædia we gave a comparison of five proofs of Taylor's Theorem. This was twenty years ago: since which time the character of elementary works has changed. The Penny Cyclopædia being still perfectly accessible, we think it will be best to confine ourselves, in the present work, to a statement of the best form of the best proof. This we hold to be a variation and amendment, by Mr. Homersham Cox, of Cauchy's proof, which may be seen in De Morgan's Differential Calculus. Mr. Cox's proof was first published in the Cambridge Mathematical Journal, vol. vi., p. 80.

From $\phi(a+v)$ subtract any number of Taylor's terms, and one more with an undefined constant, and write this down with as many differential coefficients as Taylor's terms: as in

$$\text{P} \quad \phi(a+v)-\phi a-\phi' a\, v-\phi'' a\frac{v^2}{2}-\phi''' a\,\frac{v^3}{2\,.\,3}-\text{C}\,\frac{v^4}{2\,.\,3\,.\,4}$$

$$\text{Q} \quad \phi'(a+v)-\phi' a-\phi'' a\, v-\phi''' a\frac{v^2}{2}-\text{C}\,\frac{v^3}{2\,.\,3}$$

$$\text{R} \quad \phi''(a+v)-\phi'' a-\phi''' a\, v-\text{C}\,\frac{v^2}{2}$$

$$\text{S} \quad \phi'''(a+v)-\phi''' a-\text{C}v$$

$$\text{T} \quad \phi^{\text{iv}}(a+v)-\text{C}.$$

All these vanish with v, except the last: choose for C that value which makes the first vanish when $v=h$. Let ϕx be such that $\phi^{\text{iv}} x$ (and consequently ϕx, $\phi' x$, $\phi'' x$, $\phi''' x$) does not become infinite from $x=a$ to $x=a+h$. Now remember that a function which vanishes in two places, and does not become infinite in the interval, must change from increasing to diminishing, or from diminishing to increasing, in that interval: so that its differential coefficient must change sign, and, if not infinite, must vanish. Now P satisfies these conditions, vanishing at $v=0$ and at $v=h$: hence Q must vanish before $v=h$, and as it vanishes at $v=0$, and does not become infinite in the interval, Q also satisfies the conditions: hence R vanishes before $v=h$: and by like reasoning S, and T. Now if some value of v between 0 and h makes T vanish, let it be $v=\theta h$, θ being a positive fraction between 0 and 1. Hence $\text{C}=\phi^{\text{iv}}(a+\theta h)$: and since C was so taken that P vanishes when $v=h$, we have

$$\phi(a+h)=\phi a+\phi' a\,.\,h+\phi'' a\,\frac{h^2}{2}+\phi''' a\,\frac{h^3}{2\,.\,3}+\phi^{\text{iv}}(a+\theta h)\,\frac{h^4}{2\,.\,3\,.\,4}.$$

This, if the reasoning be carried to n terms of Taylor's series, is Taylor's theorem with Lagrange's theorem on the *remainder* of the series appended. If no differential coefficient of ϕx up to $\phi^{(n)} x$ should become infinite from $x=a$ to $x=a+h$, then

$$\phi(a+h)=\phi a+\phi' a\,.\,h+\,.\,.\,.\,.\,.+\phi^{(n-1)} a\,\frac{h^{n-1}}{2\,.\,3\ldots n-1}+$$
$$\phi^{(n)}(a+\theta h)\,\frac{h^n}{2\,.\,3\ldots n}.$$

If the remainder term diminish without limit as n increases without limit, Taylor's series gives a true development.

Some views of Lambert on the reduction of the roots of equations (Acta Helvetica, 1758) into series were generalised by Lagrange (Mém. Acad. Sci., 1768) into a celebrated theorem of development bearing his name; and this again was generalised in form by Laplace (Méc. Cél.). The problem is as follows: given

$$y=\text{F}(z+x\phi y)\,.\,.\,.\,.\,(\text{A})$$

required the expansion of ψy, when possible, in powers of x. Since ψy is, by the preceding equation, a function of x and z, if z be constant, and we differentiate with respect to x, and then make $x=0$, or $y=\text{F}z$, we may use Stirling's theorem. But this differentiation would be laborious and indirect; it was made more direct (by Laplace) in the following manner:—A constant may have any value given to it, or may be made to vanish, either before or after differentiation with respect to a variable: if then we can express differentiations with respect to x in terms of differentiations with respect to z only (in which x is constant), it will be in our power to make x vanish *before* the differentiations, which will reduce the indirect or implicit to direct differentiation. This substitution of z-differentiations in place of those of x is done as follows:—Differentiate (A) both with respect to x and z separately, and we have

$$\frac{dy}{dx}=\text{F}'(z+x\phi y)\left\{\phi y+x\phi' y\,\frac{dy}{dx}\right\} \qquad \text{whence}$$

$$\frac{dy}{dz}=\text{F}'(z+x\phi y)\left\{1+x\phi' y\,\frac{dy}{dz}\right\} \quad \frac{dy}{dx}=\phi y\,\frac{dy}{dz}$$

Let u be a function of y only, that is, not of x or z except as those variables are contained in y: then

$$\frac{du}{dy}\,\frac{dy}{dx}=\phi y\,\frac{du}{dy}\,\frac{dy}{dz} \text{ or } \frac{du}{dx}=\phi y\,\frac{du}{dz}$$

From this equation only it may be shown (by INDUCTION) that

$$\frac{d^n u}{dx^n}=\frac{d^{n-1}}{dz^{n-1}}\left((\phi y^n)\,\frac{du}{dz}\right)$$

as follows. Assume the preceding to be true for one value of n, and since $(\phi y)^n \times du : dy$ is a function of y only, let it be $dv : dy$, v being another function of y.

$$\frac{d^n u}{dx^n}=\frac{d^{n-1}}{dz^{n-1}}\left(\frac{dv}{dy}\,\frac{dy}{dz}\right)=\frac{d^n v}{dz^n}$$

$$\frac{d^{n+1} u}{dx^{n+1}}=\frac{d^n}{dz^n}\left\{\frac{dv}{dx}, \text{ or } \phi y\,\frac{dv}{dz}, \text{ or } \phi y\,\frac{dv}{dy}\,\frac{dy}{dz}, \text{ or}\right.$$
$$\left.\phi y\,(\phi y)^n\,\frac{du}{dy}\,\frac{dy}{dz}, \text{ or } (\phi y)^{n+1}\,\frac{du}{dz}\right\}$$

whence the theorem remains true after writing $n+1$ for n. But it is true when $n=1$; therefore it is true for all values of n. If then we make $x=0$, or $y=\text{F}z$, which may be done before the differentiations on the second side of the equation, we have (u being ψy)

$$\left\{\frac{d^n \psi y}{dx^n}\,(x=0)\right\}=\frac{d^{n-1}}{dz^{n-1}}\left\{(\phi\text{F}z)^n\,\frac{d\psi\text{F}z}{dz}\right\}$$

Apply this to Maclaurin's Theorem, and we have *Laplace's Theorem*, namely,

$$y=\text{F}(z+x\phi y) \text{ gives } \psi y=$$
$$\psi\text{F}z+\left(\phi\text{F}z\,\frac{d\psi\text{F}z}{dz}\right)x+\frac{d}{dz}\left((\phi\text{F}z)^2\,\frac{d\psi\text{F}z}{dz}\right)\frac{x^2}{2}+, \&\text{c.}$$
$$\text{the general term, } \frac{d^{n-1}}{dz^{n-1}}\left\{(\phi\text{F}z)^n\,\frac{d\psi\text{F}z}{dz}\right\}\frac{x^n}{[n]}$$

Lagrange's theorem, from which Laplace generalised, is the case in which $\text{F}x=x$; namely,

$$y=z+x\phi y \text{ gives } \psi y=\phi z+(\phi z\psi' z)x+\frac{d}{dz}\left((\phi z)^2\,\psi' z\right)\frac{x^2}{2}+, \&\text{c.}$$
$$\text{the general term } \frac{d^{n-1}}{dz^{n-1}}\left\{(\phi z)^n\,\psi' z\right\}\frac{x^n}{[n]}$$
$$y=z+\phi z\,.\,x+\frac{d(\phi z)^2}{dz}\,\frac{x^2}{2}+\frac{d^2(\phi z)^3}{dz^2}\,\frac{x^3}{2\,.\,3}+, \&\text{c.}$$

Lagrange's Theorem leads to *Burmann's Theorem* (presented to the institute in 1796). The second is in fact the same as the first, though very different in form, and arrived at independently. It is required, when possible, to expand ψx in powers of ϕx. This might be done indirectly, by expanding $\psi\phi^{-1} x$ in powers of x, and substituting ϕx for x in the result. The form in which Burmann obtained Lagrange's theorem avoids the indirect process. Let ϕx vanish when $x=a$, and let $\phi x=(x-a):\chi x$, or $x=a+\phi x\,.\,\chi x$. We can now employ Lagrange's theorem to expand ψx in powers of ϕx, and we have

$$\psi x=\psi a+\chi a\psi' a\,.\,\phi x+\frac{d}{da}\left((\chi a)^2\,\psi' a\right)\frac{(\phi x)^2}{2}+, \&\text{c.}$$

Now the general term of this has for its coefficient the value of

$$\frac{d^{n-1}}{dx^{n-1}}\left((\chi x)^n\,.\,\psi' x\right) \text{ or } \frac{d^{n-1}}{dx^{n-1}}\left\{\left(\frac{x-a}{\phi x}\right)^n\,\psi' x\right\}$$

when $x=a$: consequently ψx, expanded in powers of ϕx, is found by making $x=a$ in the coefficients of the powers of ϕx in the following series:—

$$\phi a+\left\{\frac{x-a}{\phi x}\,.\,\psi' x\right\}\phi x+\left\{\frac{d}{dx}\left(\left(\frac{x-a}{\phi x}\right)^2\,\psi' x\right)\right\}\frac{(\phi x)^2}{2}+, \&\text{c.}$$

When, in a function of any number of variables x_1, x_2, &c., the variables are severally to receive increments h_1, h_2, &c., the law of the development is best seen by the calculus of operations. [OPERATION.] To change x into $x+h$ is to perform the operation $\varepsilon^{h\text{D}}$, D being the symbol of differentiation with respect to x: the condensed form of the development now before us is

$$\varepsilon^{h_1\text{D}_1+h_2\text{D}_2+\,.\,.\,.\,.}\ \phi(x_1, x_2, \,.\,.\,.\,.\,.)$$

where D_1, D_2, &c. refer to x_1, x_2, &c. The general term of the development is

$$\frac{(h_1\text{D}_1+h_2\text{D}_2+\,.\,.\,.\,.\,.)^n}{[n]}\,\phi(x_1, x_2, \&\text{c.})$$

which must itself be developed. It is not worth while to pursue this case further: we shall only observe that when it is desired to stop, the remnant may be obtained by writing in the last term $x_1+\theta h_1$ for x_1, $x_2+\theta h_2$ for x_2, &c., where θ, the same in all, is either 0 or 1 or between them.

The value of x which makes $\phi x=0$ is represented by

$$a-\frac{\phi}{\phi'}-\frac{\phi''\phi^2}{2\phi'^3}-\frac{(3\phi''^2-\phi'\phi''')\phi^3}{2\,.\,3\phi'^5}-\frac{(15\phi''^3-10\phi'\phi''\phi'''+\phi'^2\phi^{\text{iv}})\phi^4}{2\,.\,3\,.\,4\,\phi'^7}$$
$$-\frac{\{105\phi''^2(\phi''^2-\phi'\phi''')+10\phi'^2\phi'''^2+15\phi'^2\phi''\phi^{\text{iv}}-\phi'^3\phi\}\phi^5}{2\,.\,3\,.\,4\,.\,5\phi'^9}-\&\text{c.}:$$

where a is any assumed value (the nearer the root the better) and ϕ, ϕ', &c. represent ϕa, $\phi' a$, &c. This series is obtained by common reversion from $\phi(a+h)=0$. For the forms which Paoli gave to this series, and also to Burmann's, see Lacroix, vol. i., pp. 306-308. The preceding series has been used, as far as three terms, in the article **Approximation.**

All that precedes is found in elementary treatises, with the exception of a few terms of the last series: we now come to matter which has been hitherto only the property of the well-read mathematician, but which well deserves to be made as common as Taylor's Theorem. We refer to Arbogast's *method of derivations.* [ARBOGAST, in BIOG. DIV.] Few, even among mathematicians, are aware of the power of this process, which may perhaps arise from their taking Lacroix's account of it, instead of consulting the work of Arbogast himself: the former has only exhibited it to show that it may be reduced to processes of the differential calculus; and even the latter has so loaded his method with heavy applications, that he has concealed much of its beauty and simplicity.

The foundation of Arbogast's methods is a contrivance for expediting the expansion of $\phi(a+bx+cx^2+\ldots.)$ into a series of the form $\mathrm{A}+\mathrm{B}x+\mathrm{C}x^2+\ldots..$ The process by which B is formed from A, C from B, &c. is uniform, and is called derivation; and A being ϕa, B may be called $\mathrm{D}\phi a$, C may be called $\mathrm{DD}\phi a$, or $\mathrm{D}^2\phi a$, and so on. Hence b ought to be called $\mathrm{D}a$, c ought to be D^2a, and so on. This notation is not precisely that of Arbogast, but will do for our purpose. For more detail,* see the Differential Calculus ('Library of Useful Knowledge'), pp. 328-334.

If, for a moment, we write the expansion thus—

$$\phi(a_0+a_1x+a_2x^2+\ \&\text{c.}) = \mathrm{A}_0+\mathrm{A}_1x+\mathrm{A}_2x^2+\ \&\text{c.}$$

and if we differentiate both sides with respect to a_m, x and all the other coefficients remaining constant, we have

$$\phi'(a_0+a_1x+\&\text{c.})\,.\,x^m = \frac{d\mathrm{A}_0}{da_m} + \frac{d\mathrm{A}_1}{da_m}x+,\&\text{c.}$$

which shows that a_m cannot enter any coefficient preceding A_m, or

$$\phi'(a_0+a_1x+\&\text{c.}) = \frac{d\mathrm{A}_m}{da_m} + \frac{d\mathrm{A}_{m+1}}{da_m}x+,\&\text{c.}$$

The first side of this is the same series, whatever letter a_m was made to vary; the second side is therefore always the same series; whence we collect that $d\mathrm{A}_{m+n} : da_m$ does not alter with the value of m, being always the coefficient of x^n in the development of $\phi'(a_0+a_1x+,\&\text{c.})$. It is enough to satisfy this condition for each letter and its preceding one; that is to say, each coefficient differentiated with respect to any one letter, is to yield the same result as the directly preceding coefficient differentiated with respect to the directly preceding letter. The following rules are found sufficient. To pass from any one derivative of ϕa to the next, arrange the letters a, b, c, &c., or a_0, a_1, a_2, &c., whichever may be used, in order, in every term: differentiate with respect to the last letter in each term, and multiply by the letter which comes next to it. And when the last but one immediately precedes the last in the alphabet or other consecutive system, do the same with the last but one, and divide by the exponent of the last letter, as it becomes after the increase which it receives from the process of the preceding letter; but in no case use any letters but the last or the last but one. For instance, beginning with ϕa, in which is only one letter, we have $\phi'a\,.\,b$, or

$$\mathrm{D}\phi a = \phi'a\,.\,b\,;$$

in which are two letters, a and b, consecutive. Operate upon b, and we have $\phi'a\,.\,c$; operate on $\phi'a$, and we have again $\phi''a\,.\,b$, which, with the b which was in before, is $\phi''a\,.\,b^2$, which we divide by the new exponent of b, or by 2, whence

$$\mathrm{D}^2\phi a = \phi'a\,.\,c + \frac{\phi''a}{2}b^2.$$

In forming $\mathrm{D}^3\phi a$, we use only c in $\phi'a\,.\,c$, because a does not immediately precede c; and we get (the succession being a, b, c, e, f, g, h, k, &c.)

$$\mathrm{D}^3\phi a = \phi'a\,.\,e + \frac{\phi''a}{2}\,.\,2bc + \frac{\phi'''a}{2\,.\,3}b^3;$$

and so on. As soon however as the law is established, it is best to form a table of the successive derivatives of the powers of b by this same law: we then have

$$\mathrm{D}^n\phi a = \phi'a\mathrm{D}^{n-1}b + \frac{\phi''a}{2}\mathrm{D}^{n-2}b^2 + \frac{\phi'''a}{2\,.\,3}\mathrm{D}^{n-3}b^3 + \&\text{c.}$$

$$\text{as far as } \frac{\phi^n a}{[n]}b^n;$$

in which $\phi'a$, $\phi''a$, &c. are to be taken from the function by common differentiation, and the derivatives of the powers of b from the table. This being done, we have

$$\phi(a+bx+cx^2+ex^3+fx^4+gx^5+,\&\text{c.}) =$$
$$\phi a + \mathrm{D}\phi a\,.\,x + \mathrm{D}^2\phi a\,.\,x^2 + \mathrm{D}^3\phi a\,.\,x^3+,\&\text{c.}$$

and the process is shortened to its utmost extent; all that is not differentiation being merely reference to a table and writing the result.

We shall give materials for proceeding as far as the term $\mathrm{D}^{12}\phi a\,.\,x^{12}$, not that so much will often be necessary, but because it is desirable to show with how little trouble questions of enormous labour in the ordinary way, such, for instance, as that solved in **Reversion of Series**, may be looked at without dismay. We have to form every derivative of every power of b, $\mathrm{D}^m b^n$, in which $m+n$ does not exceed 12.

$\mathrm{D}b=c$ $\mathrm{D}^2b=e$ $\mathrm{D}^3b=f$ $\mathrm{D}^4b=g$
$\mathrm{D}^5b=h$ $\mathrm{D}^6b=k$ $\mathrm{D}^7b=l$ $\mathrm{D}^8b=m$
$\mathrm{D}^9b=n$ $\mathrm{D}^{10}b=p$ $\mathrm{D}^{11}b=q$

$\mathrm{D}b^2=2bc$
$\mathrm{D}^2b^2=2be+c^2$
$\mathrm{D}^3b^2=2bf+2ce$
$\mathrm{D}^4b^2=2bg+2cf+e^2$
$\mathrm{D}^5b^2=2bh+2cg+2ef$
$\mathrm{D}^6b^2=2bk+2ch+2eg+f^2$
$\mathrm{D}^7b^2=2bl+2ck+2eh+2fg$
$\mathrm{D}^8b^2=2bm+2cl+2ek+2fh+g^2$
$\mathrm{D}^9b^2=2bn+2cm+2el+2fk+2gh$
$\mathrm{D}^{10}b^2=2bp+2cn+2em+2fl+2gk+h^2$

$\mathrm{D}b^3=3b^2c$
$\mathrm{D}^2b^3=3b^2e+3bc^2$
$\mathrm{D}^3b^3=3b^2f+6bce+c^3$
$\mathrm{D}^4b^3=3b^2g+6bcf+3be^2+3c^2e$
$\mathrm{D}^5b^3=3b^2h+6bcg+6bef+3c^2f+3ce^2$
$\mathrm{D}^6b^3=3b^2k+6bch+6beg+3bf^2+3c^2g+6cef+e^3$
$\mathrm{D}^7b^3=3b^2l+6bck+6beh+6bfg+3c^2h+6ceg+3cf^2+3e^2f$
$\mathrm{D}^8b^3=3b^2m+6bcl+6bek+6bfh+3bg^2+3c^2k+6ceh+6cfg+3e^2g$
$\qquad+3ef^2$
$\mathrm{D}^9b^3=3b^2n+6bcm+6bel+6bfk+6bgh+3c^2l+6cek+6cfh+3cg^2$
$\qquad+3e^2h+6efg+f^3$

$\mathrm{D}b^4=4b^3c$
$\mathrm{D}^2b^4=4b^3e+6b^2c^2$
$\mathrm{D}^3b^4=4b^3f+12b^2ce+4bc^3$
$\mathrm{D}^4b^4=4b^3g+12b^2cf+6b^2e^2+12bc^2e+c^4$
$\mathrm{D}^5b^4=4b^3h+12b^2cg+12b^2ef+12bc^2f+12bce^2+4c^3e$
$\mathrm{D}^6b^4=4b^3k+12b^2ch+12b^2eg+6b^2f^2+12bc^2g+24bcef+4be^3+4c^3f$
$\qquad+6c^2e^2$
$\mathrm{D}^7b^4=4b^3l+12b^2ck+12b^2eh+12b^2fg+12bc^2h+24bceg+12bcf^2$
$\qquad+12be^2f+4c^3g+12c^2ef+4ce^3$
$\mathrm{D}^8b^4=4b^3m+12b^2cl+12b^2ek+12b^2fh+6b^2g^2+12bc^2k+24bceh$
$\qquad+24bcfg+12be^2g+12bef^2+4c^3h+12c^2eg+6c^2f^2$
$\qquad+12ce^2f+e^4$

$\mathrm{D}b^5=5b^4c$
$\mathrm{D}^2b^5=5b^4e+10b^3c^2$
$\mathrm{D}^3b^5=5b^4f+20b^3ce+10b^2c^3$
$\mathrm{D}^4b^5=5b^4g+20b^3cf+10b^3e^2+30b^2c^2e+5bc^4$
$\mathrm{D}^5b^5=5b^4h+20b^3cg+20b^3ef+30b^2c^2f+30b^2ce^2+20bc^3e+c^5$
$\mathrm{D}^6b^5=5b^4k+20b^3ch+20b^3eg+10b^3f^2+30b^2c^2g+60b^2cef+10b^2e^3$
$\qquad+20bc^3f+30bc^2e^2+5c^4e$
$\mathrm{D}^7b^5=5b^4l+20b^3ck+20b^3eh+20b^3fg+30b^2c^2h+60b^2ceg+30b^2cf^2$
$\qquad+30b^2e^2f+20bc^3g+60bc^2ef+20bce^3+5c^4f+10c^3e^2$

$\mathrm{D}b^6=6b^5c$
$\mathrm{D}^2b^6=6b^5e+15b^4c^2$
$\mathrm{D}^3b^6=6b^5f+30b^4ce+20b^3c^3$
$\mathrm{D}^4b^6=6b^5g+30b^4cf+15b^4e^2+60b^3c^2e+15b^2c^4$
$\mathrm{D}^5b^6=6b^5h+30b^4cg+30b^4ef+60b^3c^2f+60b^3ce^2+60b^2c^3e+6bc^5$
$\mathrm{D}^6b^6=6b^5k+30b^4ch+30b^4eg+15b^4f^2+60b^3c^2g+120b^3cef+20b^3e^3$
$\qquad+60b^2c^3f+90b^2c^2e^2+30bc^4e+c^6$

$\mathrm{D}b^7=7b^6c$
$\mathrm{D}^2b^7=7b^6e+21b^5c^2$
$\mathrm{D}^3b^7=7b^6f+42b^5ce+35b^4c^3$
$\mathrm{D}^4b^7=7b^6g+42b^5cf+21b^5e^2+105b^4c^2e+35b^3c^4$
$\mathrm{D}^5b^7=7b^6h+42b^5cg+42b^5ef+105b^4c^2f+105b^4ce^2+140b^3c^3e$
$\qquad+21b^2c^5$

$\mathrm{D}b^8=8b^7c$
$\mathrm{D}^2b^8=8b^7e+28b^6c^2$
$\mathrm{D}^3b^8=8b^7f+56b^6ce+56b^5c^3$
$\mathrm{D}^4b^8=8b^7g+56b^6cf+28b^6e^2+168b^5c^2e+70b^4c^4$

$\mathrm{D}b^9=9b^8c$
$\mathrm{D}^2b^9=9b^8e+36b^7c^2$
$\mathrm{D}^3b^9=9b^8f+72b^7ce+84b^6c^3$

$\mathrm{D}b^{10}=10b^9c$ $\mathrm{D}^2b^{10}=10b^9e+45b^8c^2$

$\mathrm{D}b^{11}=11b^{10}c$

To verify these results, observe that if we consider each letter as of the first dimension, every term of $\mathrm{D}^n b^r$ is of the rth dimension; but if we consider each letter as of the dimension following:—

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* There is a great deal on the subject in the 'Mathematical Treatises' (posthumous) of the Rev. John West, published at Edinburgh in 1838. Mr. West has substituted a notation, for that of Arbogast, in which he will probably have few followers. The student who is not repelled by this, and cannot procure Arbogast's work, will find West's treatises abounding in derivations.

$$\begin{array}{cccccccccccc} b & c & e & f & g & h & k & l & m & n & p & q \\ 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12: \end{array}$$

then every term of $\mathrm{D}^n b^r$ is of the $(n+r)$th dimension. To find out if all the proper terms be there, and with the proper exponents, write down the number of ways in which $n+r$ can be made out of r numbers. Thus, to verify this point for D^7b^3, write down the ways in which 10 can be made out of three numbers, namely:—

$$8+1+1,\ 7+2+1,\ 6+3+1,\ 6+2+2,\ 5+4+1,\ 5+3+2,\ 4+4+2,\ 4+3+3;$$

take the letter answering to each number, in the above list, and multiply the letters of each set together, which gives

$$b^2l,\ bck,\ beh,\ c^2h,\ bfg,\ ceg,\ cf^2,\ e^2f,$$

which are, coefficients excepted, the terms of D^7b^3 in the table. To verify the coefficients separately, observe that the coefficient of that term of $\mathrm{D}^n b^r$ which contains the sth power, tth power, &c., is

$$\frac{1\,.\,2\,.\,3\,....\,(r-1)r}{1\,.\,2\,.\,3\,...\,s \times 1\,.\,2\,.\,3\,...\,t \times .....}.$$

Thus, in D^4b^8, the term containing b^5c^2e ought to be multiplied by

$$\frac{1\,.\,2\,.\,3\,.\,4\,.\,5\,.\,6\,.\,7\,.\,8}{1\,.\,2\,.\,3\,.\,4\,.\,5 \times 1\,.\,2 \times 1}, \text{ or 168, as is the case.}$$

But the best general mode of verification is derived from the theorem

$$\mathrm{D}^n b^{r-1} = \frac{1}{r}\,\frac{d\mathrm{D}^n b^r}{db}, \text{ or } \mathrm{D}^{n+1} b^{r-1} = \frac{1}{r}\,\mathrm{D}\left(\frac{d\mathrm{D}^n b^r}{db}\right);$$

that is, having a certain derivative of a certain power, the next higher derivative of the next lower power may be found by differentiating with respect to b, dividing by the exponent of the original power, and then performing the derivation. Thus:—

$$\mathrm{D}^3b^9 = 9b^8f + 72b^7ce + 84b^6c^3,$$

differentiate with respect to b, and divide by 9, which gives

$$8b^7f + 56b^6ce + 56b^5c^3.$$

Now derive, which gives

$$8b^7g + 56b^6cf + 28b^6e^2 + 168b^5c^2e + 70b^4c^4,$$

the same as is found in the table for $\mathrm{D}^{3+1}b^{9-1}$. Here we verify the earlier result of the table from the later: to verify the later from the earlier, use the following:—

$$\mathrm{D}^n b^r = \mathrm{D}^{n-1}c\,.\,r\,b^{r-1} + \mathrm{D}^{n-2}c^2\,.\,r\,\frac{r-1}{2}\,b^{r-2}+, \text{ \&c.}$$

$$\text{up to } c^n\,\frac{r(r-1).....\ (r-n+1)}{1\,.\,2\,......\,n}\,b^{r-n},$$

in which the derivatives of powers of c must be formed from the corresponding tabular ones of b, by changing each letter into the next following. There are thus abundant means of verification. We will mention yet one method more. Only the last letter and the last but one (and that only when the two letters are consecutive) are used in the derivations. If we use any letter, no new term is produced, but only a repetition of those which other terms give. For instance, in D^6b^5 is the term $60b^2cef$; and in passing to D^7b^5, we derive from f because it is the last letter; and from e because, being the last but one, it immediately precedes f in the series. We do not here use b and c at all; but if we did use them, we should only repeat terms which will come into D^7b^5 from other sources. Thus:—$60b^2cef$ gives, from f, $60b^2ceg$, which is set down in D^7b^5; from e, $60b^2cff \div 2$, or $30b^2cf^2$, which is also set down; from c, if c had been used, we should have had $60b^2eef \div 2$, or $30b^2e^2f$, which, on looking, we find set down, as arising from the last letter of $10b^2e^3$. From b, in $60b^2cef$, had it been used, we should have got $120bccef \div 2$, or $60bc^2ef$, which is also found, and arises from the last letter of $30bc^2e^2$. If then we ever find that derivation from one of the unused letters gives anything but what arises from some of the letters which are used, it is a sign that some error has been committed.

By help of the preceding method, expansions which analysts usually avoid as much as possible, at almost any expense of circumoperation, are carried on with the greatest facility even further than is necessary. The development of $\phi(a+bx+cx^2+\text{ \&c.})$, already given, is one instance; the process in REVERSION OF SERIES is another. This last is done by expanding x in powers of $ax+bx^2+$, &c., by Burmann's Theorem, and making the expansion of the negative powers of $(a+bx+cx^2+$, &c.), which will be wanted, by the method of derivations. We shall state some further applications:—

$$(b+cx+ex^2+\text{ \&c.})^m = b^m + \mathrm{D}b^m\,.\,x + \mathrm{D}^2b^m\,.\,x^2+, \text{ \&c.}$$

When m is integer, these derivatives are in the table. When $b+cx+$, &c., is a finite series, the whole result is brought out with great ease, compared with the trouble of the common algebraical operation: in this case, the value of every letter after the last in the finite series is 0, or the last letter of that series is not to be employed in derivation. Let the reader try for himself $(b+cx+ex^2+fx^3)^5$ by this mode and then in the common way, going only so far in the latter as to feel sure that the former is of no trouble compared with it. Let m, $m\,\frac{m-1}{2}$, &c., be denoted by m, m_2, &c.

$$\begin{aligned}(a+bx+cx^2+\text{ \&c.})^m = a^m &+ mba^{m-1}x \\ &+ (mac+m_2b^2)\,a^{m-2}x^2 \\ &+ (ma^2e+m_2a\mathrm{D}b^2+m_3b^3)\,a^{m-3}x^3 \\ &+ (ma^3f+m_2a^2\mathrm{D}^2b^2+m_3a\mathrm{D}b^3+m_4b^4)\,a^{m-4}x^4\ +, \text{ \&c.};\end{aligned}$$

the law of which is evident, the only thing left being the substitution of the values in the tables instead of the derivatives of b. This form is convenient for fractional or negative powers. The following case is worth exhibiting separately:—

$$\frac{1}{a+bx+, \text{ \&c.}} = \frac{1}{a} - \frac{b}{a^2}x + \frac{b^2-ac}{a^3}x^2 - \frac{b^3-a\mathrm{D}b^2+a^2e}{a^4}x^3 + \frac{b^4-a\mathrm{D}b^3+a^2\mathrm{D}^2b^2-a^3f}{a^5}x^4 -, \text{ \&c.}$$

We have avoided the formality of writing $\mathrm{D}b$ for c, D^2b for e, &c.

$$\begin{aligned}\frac{\mathrm{A}+\mathrm{B}x+\mathrm{C}x^2+, \text{ \&c.}}{a+bx+cx^2+, \text{ \&c.}} &= \frac{\mathrm{A}}{a} - \frac{\mathrm{A}b-\mathrm{B}a}{a^2}x \\ &+ \frac{\mathrm{A}(b^2-ac)-\mathrm{B}ab+\mathrm{C}a^2}{a^3}x^2 \\ &- \frac{\mathrm{A}(b^3-a\mathrm{D}b^2+a^2e)-\mathrm{B}a(b^2-ac)+\mathrm{C}a^2b-\mathrm{E}a^3}{a^4}x^3+, \text{ \&c.}\end{aligned}$$

The law is here evident enough; the next numerator would be

$$\mathrm{A}(b^4-a\mathrm{D}b^3+a^2\mathrm{D}^2b^2-a^3f)-\mathrm{B}a(b^3-a\mathrm{D}b^2+a^2e)+\mathrm{C}a^2(b^2-ac)-\mathrm{E}a^3b+\mathrm{F}a^4.$$

The derivatives of the general term b^n may be readily formed, but the particular cases are more useful; see the derivatives of a^m in the general form above given. We shall not overload this subject with further examples: enough have been given to show those who require developments of some extent how much labour they might save.

We shall conclude this article by recommending that the process of derivation should be introduced, without demonstration, of course, into elementary books of algebra, as one of the best exercises of simple algebraical operation. We are firmly of opinion that the arithmetician and the analyst should be trained early in the performance of operations in which numerous details, each very simple in itself, follow one another in rapid succession with much sameness and some diversity. For this reason we should recommend, in arithmetic, Horner's process [INVOLUTION AND EVOLUTION]; and in algebra, Arbogast's derivation. We proceed accordingly to divest this method of the phraseology of the differential calculus, and to put it before the elementary student in algebra.

The name of the process is *derivation;* its primary object the raising of any power of an expression of the form $b+cx+ex^2+fx^3+$, &c., immediately—that is to say, by writing down the result at once, without any but simple mental processes in passing from term to term. The rules are as follows:—

1. Begin with that power of b which is to be raised.

2. To pass from the coefficient of one power of x to that of the next, multiply each letter by its exponent; then diminish that exponent by a unit; then introduce the next letter. And if this last process increase an exponent, owing to the letter newly introduced having been in the term before, divide by the increased exponent. *But remember never to operate on any letter except the last in the term, or the last but one;* upon the last always, upon the last but one when it immediately precedes the last in the original series b, c, e, f, &c.

3. If $b+cx+$, &c., be not an infinite series, but a finite number of terms, operate as if the succeeding letters were severally equal to 0: for instance, if g be the last letter, drop every term in which h should appear, as fast as it arises.

For example, the fifth power of $b+cx+ex^2+fx^3$. Begin with b^5, derive from it $5b^4c$, the two first terms are $b^5+5b^4c\,.\,x$.

To form the coefficient of x^2, take $5b^4c$, and observe that b and c follow each other in the series, so that in the next derivation there are two processes. First, use c or c^1, the last letter, which by the rule gives $1c^0e$ or e: so that derivation applied to the first power of a letter gives merely a change of that letter into the next: hence $5b^4c$ gives $5b^4e$. But b^4, which must also be used, gives $4b^3c$, and $5b^4c$ gives $5(4b^3c)c$; so that c becomes c^2, and we must therefore divide by the increased exponent 2, giving $10b^3c^2$. Hence the next term is

$$(5b^4e+10b^3c^2)x^2.$$

In the next derivation $5b^4e$ gives only $5b^4f$, for b not immediately preceding e in the series b, c, e, &c., is not used. But $10b^3c^2$ gives

$$10b^3(2ce) + \frac{10(3b^2c)c^2}{3}, \text{ or } 20b^3ce+10b^2c^3.$$

Next term $(5b^4f+20b^3ce+10b^2c^3)x^3$.

In the next derivation $5b^4f$ must be neglected entirely, because f is the last letter, and b is not the one immediately preceding. Also $20b^3ce$ gives $20b^3cf$ and $20b^3ee \div 2$, or $10b^3e^2$; while $10b^2c^3$ gives $30b^2c^2e$

and $2 \times 10bc \cdot c^3 \div 4$, or $5bc^4$. The whole value of $(b+cx+ex^2+fx^3)^5$ is as follows, and a little practice would enable any one to write it down at once, without any intermediate operations :—

$$\begin{aligned}
&b^5+5b^4cx+(5b^4e+10b^3c^2)x^2+(5b^4f+20b^3ce+10b^2c^3)x^3\\
&+(20b^3cf+10b^3e^2+30b^2c^2e+5bc^4)x^4\\
&+(20b^3ef+30b^2c^2f+30b^2ce^2+20bc^3e+c^5)x^5\\
&+(10b^3f^2+60b^2cef+10b^2e^3+20bc^3f+30bc^2e^2+5c^4e)x^6\\
&+(30b^2cf^2+30b^2e^2f+60bc^2ef+20bce^3+5c^4f+10c^3e^2)x^7\\
&+(30b^2ef^2+30bc^2f^2+60bce^2f+5be^4+20c^3ef+10c^2e^3)x^8\\
&+(10b^2f^3+60bcef^2+20be^3f+10c^3f^2+30c^2e^2f+5ce^4)x^9\\
&+(20bcf^3+30be^2f^2+30c^2ef^2+20ce^3f+e^5)x^{10}\\
&+(20bef^3+10c^2f^3+30ce^2f^2+5e^4f)x^{11}\\
&+(5bf^4+20cef^3+10e^3f^2)x^{12}+(5cf^4+10e^2f^3)x^{13}+5ef^4x^{14}+f^5x^{15}
\end{aligned}$$

This process, so simple as compared with the actual performance of the four multiplications, has hitherto lain hid in works on the higher parts of the differential calculus: it is time it should take its place in every system of algebra which contains the binomial theorem, of which it is the legitimate extension.

TEA AND THE TEA TRADE. Though now so extensively employed, the introduction of tea into Europe is of comparatively recent origin. Macpherson, in his 'History of European Commerce with India,' states that "tea (sah) is mentioned as the usual beverage of the Chinese by Soliman, an Arabian merchant, who wrote an account of his travels in the East about the year A.D. 850;" but that he had been unable to find any other mention of it prior to the times of the Jesuit missionaries, who entered China and Japan a little before the middle of the 16th century. Anderson, in his 'History of Commerce,' quotes Botero as giving the earliest account in 1590, when he says that the Chinese, "have also an herb, out of which they press a delicate juice, which serves them as drink instead of wine." Texeira, a native of Portugal, about the year 1600, saw the dried leaves of tea at Malacca; and Olearius found them used in 1633 by the Persians, who obtained them from China by means of the Usbeck Tartars. Tea, coffee, and chocolate are all mentioned in an act of parliament of 1660, whereby a duty of 8*d.* is charged on every gallon of chocolate, sherbet, and tea made for sale. But the use of it in England at that time must have been new; for Pepys in his 'Diary,' writes, September 25, 1661, "I sent for a cup of tea (a Chinese drink), of which I had never drank before." The Dutch East India Company probably first introduced it into Europe, and from Amsterdam it was brought to London. But tea must have continued to be brought in small quantities only; for in the year 1664 the East India Company purchased, for the purpose of presenting to the king, 2 lbs. and 2 ozs. of tea; and in the year 1678 they imported 4713 lbs. of tea, which was then for the first time thought worth their attention as a branch of their trade. ('Macpherson,' p. 131.)

The botanical characters of the chief species of the tea-plant are described in the NAT. HIST. DIV., under the name of the genus THEA, to which they belong.

Tea Cultivation.—Tea is cultivated in China over a great extent of territory. Dr. Wallich mentions it as being cultivated in Cochin China, in 17° N. lat. We know that it is cultivated in the southern provinces of Yunnan and of Canton. Farther north the principal cultivation of teas for the foreign trade is between 27° and 31° N. lat.: but tea is said to be produced in several places to the north of 31°; even in 36°, and also in the Japanese Islands, which extend from 30° to 41° N. lat. It is generally said to be cultivated in hilly situations. Grosier states that the songlo-tcha (our green tea) takes its name from the mountain Song-lo, situated in the province of Kiangnan, in 30° N. lat.; while the bou-y tcha (bohea) takes its name from a mountain called Bou-y, situated in the province of Fo-kien. Mr. Cunningham (at the time when Chusan had a British factory) collected specimens on the tops of mountains, where the tea-plant flourished along with pines. The deputation sent into Asam to examine the sites of the tea, saw it growing in the valley of Asam, and were thus led to think that it must grow in similar situations in China; but even in Asam it is also found on hills; and there is no doubt that it is found in both situations in China, and in many which must be moist, though it is probable that the finest varieties of tea are cultivated in the drier soils, and in situations exposed to light and air. Some soils in which the tea-plant is cultivated in China yielded, on analysis, in 200 parts—of silex, 135; alumina, 36; carbonate of magnesia, 6; carbonate of lime, 4; oxide of iron, 13; roots and fibres of plants, 2; water of absorption, 4. Dr. Abel thought that the débris of granitic rocks would yield a fitting soil, and that the Cape of Good Hope would afford a suitable climate.

The culture of the tea-plant in China seems simple enough. The plants are raised from seeds, sown in the places where they are to remain. Several are dropped into holes 4 or 5 inches deep and 3 or 4 feet apart, shortly after they ripen; or in November and December, as they do not preserve well, from their oiliness. The plants rise up in a cluster when the rain comes on, and require little further care, except that of removing weeds, till they are three years old, when they yield their first crop of leaves. They are seldom transplanted; but sometimes four to six plants are put close together, so as to form a fine bush. After growing seven or ten years they are cut down, in order that the numerous young shoots which then spring out may afford a more abundant supply of leaves. In some districts the bushes grow unrestrained, in others they are regularly pruned, to keep them low. The gathering of the leaves is performed with great care: they are usually gathered singly, first in March or April (according to the district), when the young leaves are scarcely expanded; the second about two months later, or May and June; and the third in August, or about six weeks after the second; but the times necessarily differ in different districts, as well as the number of crops which are obtained, some growers avoiding the third, for fear of injuring the bushes. When the leaves are gathered they are dried in houses that contain small furnaces, on each of which there is a flat iron pan; upon this, when heated, the leaves, partially dried by exposure to the sun, are thrown; the leaves require frequent shifting and turning. When all are properly dried, they are quickly removed either by the hand or with a shovel, and either thrown upon a mat or into baskets kept ready to receive them. They are then removed to a table where they are rolled and cooled, and the process is repeated; after which they are sifted and sorted into several varieties.

It is difficult to determine whether the green and black teas are produced by one or two distinct species of plants; as the statements of apparently equally well qualified judges are not only contradictory, but directly the reverse of each other. The difficulty is owing partly to the Chinese in the neighbourhood of Canton being able to prepare a tea which can be coloured and made up to imitate various qualities of green tea; and large quantities are thus yearly made up. The Chinese tea-makers in Asam and those in Java alike state that the black and green teas may be prepared from the same plant. But as there are plants of the genus *Thea*, of which the leaves resemble some the black and some the green teas of commerce, and as these differ very considerably from each other in their powers of resisting cold, and as there are green tea and black tea districts (the former to the north of the latter), it seems probable that different plants are preferred for preparing the finer qualities of these different teas.

Tea having become so extensive an article of commerce, and a source of considerable revenue, various attempts have been made to introduce it into other countries. The climates are very different in which the several experiments have been made; such as in Rio Janeiro and the warm part of Brazil, and latterly in the hilly parts of Java and Brazil, in Penang, Asam, and the Himalayas. Dr. Abel recommended the Cape of Good Hope. It is requisite to have not only a suitable soil and climate, but also cheap and abundant labour. Many have been of opinion that tea could be cultivated in the Himalayas, but the first published opinions seem to be those of Dr. Royle ('Illustr. Himalayan Botany,' p. 5 and 107, and 'Productive Resources of India,' p. 259), where, from a consideration of a similarity in latitude, climate, and vegetation, as far as any information could be procured on those subjects, he was of opinion that tea could be successfully cultivated in the Himalayan mountains; "for the different elevations allow of every variety of climate being selected, and the geographical distribution of this plant is sufficiently extended, and the natural sites sufficiently varied, to warrant its being beneficially cultivated." He recommended experiments being made in that tract of the Himalayas which extends from Almorah nearly to the Sutlej, at various elevations from the valleys up to 7000 feet, and thought that about 5000 feet of elevation would afford a suitable climate. Dr. Falconer formed similar opinions at the same time in a report to government. The correctness of these opinions has been clearly proved by the success of the tea plantations established in the Kumaon and Gurhwal districts of these mountains, which were formed when the tea nurseries were established in Asam, and the seeds and plants sent up which had been obtained from China.

The Asam tea-plant first attracted public attention in 1834, in consequence of replies to the circulars which had been addressed to several gentlemen. Captains Jenkins and Charlton, in May of that year, wrote that a kind of tea-plant was undoubtedly indigenous in Asam. Since then it has appeared that several gentlemen were well aware of the fact, and also that Mr. David Scott had, in June, 1825, sent leaves and seeds of a plant discovered originally by Major Bruce, which he said the Burmese and Chinese concurred in stating to be wild tea. A scientific deputation, composed of Dr. Wallich and Messrs. Griffith and MacCleland, was sent for the proper investigation of Upper Asam. Tea plantations were subsequently established, and Mr. Bruce was appointed their superintendent. Mr. MacCleland states that the tea tracts are found in Asam, first on the level plain and secondly on mounds or hillocks, and that the former situations have a porous structure which enables them to maintain a dry surface under exposure to excessive moisture. Asam teas were first sold in 1839; and from the excitement and competition created by the novelty of the sale, such extravagant prices were paid as from 16*s.* to 34*s.* a pound; but they in due time found their true level.

Recent explorations have rendered it probable that the tea-plant is growing wild in the forests and jungles of Upper Asam, the Sylhet Hills, the Himalaya, and the great range of mountains extending thence through China to the Yang-tse-Kiang. If so, its extended artificial culture may reasonably be expected. Mr. Leonard Wray, in an elaborate paper on the Cultivation of Tea, read before the Society of Arts in January, 1861, gives an account of the recent proceedings on that subject in India. The Asam Tea Company, after many commercial discouragements, have brought their affairs into a healthy condition. They now own 4000 acres of land, which yielded 1,000,000 lbs. of tea in the year 1860. This tea, selling in England (wholesale, and minus the duty) at an average of about 2*s.* per lb., is strong, coarse, harsh, and astringent, and is considered to be well fitted for mixing with China tea, which is mostly of weaker quality. There is another company, and there are many private individuals, also cultivating tea in Assam. Still more important are the operations which the India government has for several years been conducting in the North-West provinces, under the able management of Dr. W. Jameson. Begun on a small scale in 1885, they have now become very extensive. In 1859 the government tea plantations in Kumaon, Gurhwal, Deyra Dhoon, and the Kangra Valley comprised 2250 acres and seven factories. The Bohea variety is that chiefly cultivated. The government established these tea plantations with a view to the making of experiments, and the encouragement of companies and private speculators; and a liberal transmission of seeds and young plants is granted to beginners. Land fit for the tea-culture is also granted by the government on very liberal terms; and of such land there is believed to be not less than a million acres in the North-West provinces alone. The experience of 1859 showed that a handsome profit is derivable from the culture; and numerous persons are embarking in the enterprise. Many of these persons are military officers lately in the East India Company's service, who find the healthy climate of the hill districts suitable at once to themselves and their families, and to the tea-culture.

Tea-curing and Use.—Whether obtained from one species only of the genus *Thea*, or from several, all the tea of China is in commerce brought under two distinct terms, *green* tea and *black* tea. These are also distinguished as *hyson* and *bohea*. The European name *tea* is borrowed from the common language of the province Fu-kian (Fokien of D'Anville), where this article is called Tiä in their patois: at Canton it is called Tscha or Tschai. Black tea is called He-tscha, green tea Lo-tscha. The sub-varieties owe their names to other circumstances, the number of which is endless. Thus there occur in the catalogues of the Chinese merchants at least one hundred and fifty names, many of which are synonymes of other sorts, or names invented to impose on foreigners and obtain a high price. The distinguished Oriental scholar, Klaproth, gives a list of about forty genuine varieties, with an explanation of the terms applied to them. Thus Pak-ho, corrupted into Pekoe, merely means "white down," being the first sprouts, or yet hairy leaf-buds of young plants, three years old, after their first flowering. With us it is applied only to a black tea; but it is equally applicable to a green tea, which is never brought to Europe, as it is so delicate and slightly fired as to spoil by the least damp.

Though it is stated that black tea may be cured as green tea, and green tea as black, the green being cured without fermentation to which black tea is always subjected, certain it is that the preparation of the respective kinds is carried on in different parts of the empire, and a different practice pursued with the leaves from the first stage. In the green teas the leaves only are taken, being nipped off above the foot-stalk or petiole, while of the black teas the foot-stalk is always collected. "Thus black tea contains much of the woody fibre, while the green is exclusively the fleshy part of the leaf itself; which is one good reason why it should be dearer." (Davis's 'China,' ii., p. 351.) Besides this, the constant removal of the young leaf-buds, by which the plant is prevented from being-clothed with full grown leaves, which alone can elaborate the sap and contribute to the further growth of the shrub, causes it to perish earlier, and compels a more frequent renewal of the plantations. Indeed some cultivators restrict the gathering of the leaves to two harvests, instead of three, to save their plants. Those of the third gathering are large and coarse, and often so rigid that they cannot be rolled. This yields a tea so inferior in quality that it is consumed only by the poorest of the natives, or, when very bad, is, as are some of the finer kinds when spoiled, used for dyeing.

Such are the pains taken to ensure the excellence of the finest sorts of green tea, that for two or three weeks before the harvest commences the collectors, who are trained to this business from a very early age, are prohibited from eating fish or other kinds of food reckoned unclean, lest by their breath they should contaminate the leaves. They are also made to take a bath two or three times a day, and not allowed to gather the leaves with the naked fingers, but always with gloves. The finest tea may, if the proper time for gathering it be neglected, be changed into an inferior tea in one night. It is necessary to roast the leaves the same evening that they are collected, for if kept till the following day they ferment, become black, and lose much of their virtue. Previous to putting them into the iron pans or furnaces, which are heated by charcoal, they are dipped for about half a minute into boiling water. About half or three-quarters of a pound of leaves are put into the pan at once, and diligently stirred, to prevent them from being burnt. They are then removed with a shovel and thrown on mats or into baskets; and while yet hot the soft leaves are rolled between the palms of the hands, during which operation a quantity of yellowish green juice exudes from them. This process of roasting and rolling is often repeated even to the sixth or seventh time. This method is called the *dry way*: but by the *wet way* the leaves are first exposed to the vapour of boiling water, after which they are rolled and dried on the iron pans like the others. Leaves prepared in the wet way have a bright green colour; those by the dry, a dark green verging to brown. From the green tea, when prepared in the dry way, less of the above-mentioned juice exudes, a circumstance to which the greater strength of green tea is in some degree owing. The larger leaves are generally selected to be prepared in the wet way. By the process of roasting the leaves lose two-thirds of their weight; so that three pounds of fresh leaves dry into one pound of tea fit for preservation. It is by the process of roasting that the flavour is first developed, the leaves when fresh being as insipid as the bean of coffee before heat is applied. Siebold is of opinion that the agreeable violet-like flavour of tea is inherent in the leaves themselves; but most writers ascribe the different flavours of the choicer kinds of tea to the admixture of the flowers, leaves, or oils of a variety of different plants. The chief of these are the *Olea fragrans*, *Chloranthus inconspicuus*, *Gardenia florida*, *Aglaia odorata*, *Mogorium* (*Jasminum*) *Sambac*, *Vitex spicata*, *Camellia Sasanqua*, and *C. oleifera*, *Illicium anisatum*, *Magnolia Yulan*, and the *Rosa Indica odoratissima*, as well as the root of the *Iris florentina*, and *Curcuma longa* or turmeric, and the oil of *Bixa Orellana*. The Chinese annually dry many millions of pounds of the leaves of different plants, to mingle with the genuine, such as those of ash, plum, &c.; so that all the spurious leaves found in parcels of bad tea must not be supposed to be introduced into them by the dealers in this country. While the tea trade was entirely in the hands of the East India Company, few of these adulterated teas were shipped for this country, as experienced and competent inspectors with large salaries were kept at Canton, to prevent the exportation of such in the Company's ships; but since the trade has been opened, all kinds find a ready outlet; and, as the demand often exceeds the supply, a manufactured article is furnished to the rival crews.

The object of the drying and rolling is both to diminish the bulk and to enable the leaves to preserve their flavour. No tea is thought fit for use till it is a twelvemonth old; and the rich and luxurious Chinese keep the fine tea in jars, made of the finest porcelain, some of which are thought to communicate an additional aroma to the tea, and all of which have very narrow mouths (as may be observed in those brought to Europe, and sold at a high price), to retain the peculiar odour. If the tea contracts damp, it is taken out and roasted again.

To make the infusion, the Chinese pour boiling water on a small portion of the leaves; they do not allow it to stand or macerate, as is done in England, but instantly pour it off again, by which they obtain only the more volatile and stimulating portion of its principles. The poorer Chinese indeed boil the very inferior and coarse leaves, which alone are within their reach, and drink the decoction repeatedly during the day. This is done not only to extract such virtues as the tea possesses, but to qualify the water, seeing that little good drinking water is met with in China. Travellers find a supply of tea a very valuable accompaniment on long journeys, as it improves the most brackish waters. The exciting effects of fresh tea are such that it is rarely used till it has been kept twelve months, as already stated; and where indulged in, it produces great mental excitement. This property is diminished by repeated roastings, but as green tea is less exposed to heat than black, it retains more of this power. Besides, the green tea for exportation undergoes some process, which changes its colour, giving it a bluish-green hue. The Chinese themselves do not consume those kinds of green tea which are prepared for exportation. It is altogether a mistake to suppose that the colour of green tea is owing to its being dried on copper pans, as none such are used, and the most searching chemical analysis is unable to detect a trace of copper unless as a constituent of the vegetable.

The subject of the adulteration of tea has occupied a large amount of attention within the last few years. Irrespective of any adulteration, however, the value of tea varies enormously, according to its delicacy and aroma. Mr. Wray, when at Malacca, had a small quantity of "Mandarin tea" given to him by some Chinese merchants; it is a kind never sold to foreigners, but commands 50*s.* per lb. in China itself. The vast bulk of tea used by the Chinese is of poor quality; and much of the poorest is mixed to adulterate the better kinds for the English market. Mr. Wray estimates that the Chinese consume 2,000,000,000 lbs. of tea annually, more than ten times as much as they sell to all other countries. When the English tea trade with China was wholly conducted by the East India Company, it is believed that the sophistication mostly took place after the tea reached the hands of other dealers; but now the Chinese adulterate it themselves. Mr. Wray states that seven-eighths of all the tea shipped from China in 1859 was adulterated; this was publicly announced at a meeting of merchants, held in Canton in April, 1859, to consider the subject. The adulterants were found to be: spent tea-leaves from some of the provinces, unsound leaf from others, and three or four sorts of plants. When brought to this country, the tea sold at a (nominally) low price in the poorer neighbourhoods, undergoes a still further process of adulteration. This is proved, not only by the analyses of Drs. Hassell and Letheby, and others, but also by the Excise seisures which so frequently occur. All admit that imitations of good tea can be produced by very easy means; and this facility offers a perilous temptation to dishonest persons.

Tea Trade.—The period when tea was first introduced into this country has already been noticed. The first importation by the English East India Company took place in 1669, from the Company's factory at Bantam. The directors ordered their servants to "send home by their ships one hundred pounds weight of the best *tey* they could get." In 1678, 4713 lbs. were imported; but in the six following years the entire imports amounted to no more than 410 lbs. The continuous official accounts of the trade do not commence before 1725; but, according to Milburn (' Oriental Commerce'), the consumption in 1711 was 141,995 lbs.; 120,695 lbs. in 1715; and 237,904 lbs. in 1720. Then, taking periods twenty years apart, we find that the quantities entered for home consumption were, in round numbers, 1,000,000 lbs. in 1740; 4,000,000 lbs. in 1760; 5,000,000 lbs. in 1780; 20,000,000 lbs. in 1800; 22,000,000 lbs. in 1820; 32,000,000 lbs. in 1840; and 77,000,000 lbs. in 1860.

For above a century and a half the sole object of the East India Company's trade with China was to provide tea for the consumption of the United Kingdom. The Company enjoyed this trade to the exclusion of all other parties, and were bound from time to time to send orders for tea, and to provide ships to import the same, and always to have a year's consumption in their warehouses. The teas were disposed of in London, where only they could be imported, at quarterly sales; and the Company was bound to sell them to the highest bidder, provided an advance of one penny per lb. was made on the price at which each lot was put up. This price was determined by adding together the prime cost at Canton and the bare charges of freight, insurance, interest on capital, and certain charges on importation; but by the mode of calculating these items, and the heavier expenses which always attend every department of a trade monopoly, the upset prices were greatly enhanced. The prices realised at the Company's sales were however in still greater proportion beyond the upset prices; a result easily produced by a body who monopolised the sole supply; as it was only necessary that the quantity offered for sale should not be augmented in proportion to the growing demand of a rapidly increasing population. The 18 Geo. II., c. 26, passed immediately after a large reduction of the duty had taken place, provided for such a contingency as this, by enacting that if the East India Company failed to import a quantity sufficient to render the prices as low as in other parts of Europe, it should be lawful to grant licences to other persons to import tea. This would have constituted a very efficient check if it had been acted upon; but eventually the mode of levying the duty gave the government almost the same interest in a restricted supply as the East India Company. The duties were collected *ad valorem* on the amount realised at the Company's sales; and thus the very circumstance which enhanced the price raised the total amount of duty. The duty, at that time, was nominally 90 and 100 per cent. *ad valorem*, but being charged on a monopoly price, the difference on the cheaper teas consumed by the working and middle classes amounted to above 300 per cent. on the cost price of the same teas at Hamburg; and in 1830 the difference between the prices realised at the Company's sales and the Hamburg prices amounted to a sum of 1,889,975*l.* The sales in the last year of the East India Company's monopoly are shown in the following table :—

An Account of the Quantity and Prices of several sorts of tea sold in England from May 1st, 1833, to May 1st, 1834 :—

	lbs.	s.	d.
Bohea	6,170,963	1	10
Congou	18,053,835	2	1
Campoi	1,603	2	4
Souchong	354,515	2	9
Pekoe	514,811	2	10
Twankay	4,339,072	2	1
Hyson Skin	141,610	2	2
Hyson	987,052	3	6
Total	31,164,061		

The Company's sales were in March, June, September, and December, the latter being the largest. About 2,000,000 lbs. were offered belonging to the officers of the Company, who were allowed to import a certain quantity of tea on their own account. In 1839 there were only 122,312 lbs. offered for sale by the East India Company; and the change effected by the 3 & 4 Wm. IV., c. 93, which, on the 22nd of April, 1834, opened the trade to China, is now complete. The importation of tea is no longer confined to the port of London. In the four years ending 1834, the average annual number of ships entered inwards from China at the ports of the United Kingdom was 23; in the four following years the average was 66; other commodities besides tea have since been extensively imported, and a corresponding increase in the quantity and variety of the exports to China has taken place. The exports of tea from the United Kingdom, which formerly did not exceed 250,000 lbs. annually, amounted to 4,347,432 lbs. in 1841, and have gradually much increased. The quantity retained for home consumption has also considerably increased, although accompanied by an extraordinary increase in the use of coffee.

The tea duty has long constituted an important item in the English revenue. It has varied greatly in amount at different times. In 1725 there was a Customs' duty of 13*l.* 18*s.* 7½*d.* per 100*l.* of value, and an Excise duty of 4*s.* per lb. Sometimes, during the next period of a hundred years, the Customs' duty was raised, sometimes lowered, and on a few occasions repealed altogether; and precisely the same may be said of the Excise duty. In 1834 the Excise duty was finally repealed, and at the same time the Customs' duty was rated at 1*s.* 6*d.* to 3*s.* per lb., according to price and quality. In 1836 it was reduced to 2*s.* 1*d.* per lb. for all qualities: and in 1840 an additional 5 per cent. was imposed. During the existence of the Excise duty, it was very vexatious to the retailers. Each of the hundred thousand tea-dealers in the United Kingdom were visited once a month by the officers of excise, who took an account of their stock; and no quantity exceeding six pounds could be sent from their premises without a permit, of which above 800,000 were required in a year. In short, this system of supervision was very troublesome, costly, and answered no useful purpose. The number of tea-dealers in 1839 was 82,794 in England; 13,611 in Scotland; 12,774 in Ireland: total, 109,179. Tea is now sold by the importing merchants by public auction and private sales.

The revenue which the tea duty yielded from 1805 to 1841 was singularly uniform, never rising above 4,700,000*l.* and never falling below 3,100,000*l.* Within the last twenty years, the rate of duty and the amount received have varied much. In 1851 the duty was fixed at 2*s.*, plus 5 per cent. In Mr. Gladstone's tariff of 1853, the duty was intended to undergo successive diminutions, bringing it to 1*s.* 10*d.* in 1854, 1*s.* 3*d.* in 1855, and 1*s.* in 1856 and later years,—plus 5 per cent. A warlike expenditure so far interfered with this plan, as to prevent the lowering going beyond 1*s.* 5*d.* plus 5 per cent. In 1857 the average price of all kinds of tea in bond was exactly equal to the duty, each being about 1*s.* 6*d.* The actual prices in bond ranged from 5*d.* to 4*s.* 6*d.* per lb. Mr. M'Culloch supposes that all the Chinese tea brought to England costs on an average about 1*s.* per lb. when on board 'ship in Chinese ports, all charges included; and that this is raised to the retail consumer to 3*s.* 4*d.* by the following steps—freight, insurance, and interest 1¾*d.*, duty 1*s.* 6*d.*, wholesale and retail profits 8*d.* The average price in bond, between 1850 and 1860, varied from 1*s.* 2½*d.* to 1*s.* 6½*d.*; and the duty realised varied from 4,800,000*l.* to upwards of 6,000,000*l.* The actual trade in 1860 is represented in the following figures :—

	lbs.
Imported	88,946,532
Re-exported	12,087,104
Retained for home consumption	76,859,428

This consumption is about 2½ lb. per annum for each individual of the whole population.

On a recent occasion (May, 1861) the House of Commons consented to a renewal of the present tea duty (1*s.* 5*d.*, plus 5 per cent.) for the financial year 1861-62; supporting Mr. Gladstone in an abolition of the paper duty instead of a reduction in that on tea.

The usual net weight of a chest of tea is 138 lbs. for Bohea, 49 lbs. for Pekoe and Hyson, and 64 lbs. for Congou. So greatly does the proportion of Congou excel that of the other kinds, that 64 lbs. is considered a fair average of all the chests; this will afford an approximate rule for converting chests into lbs., in the commercial lists of imports and deliveries. The Chinese weights and moneys are of course very different from the English; but it may be convenient to know that 30 *taels* per *picul* of tea is about equal to 1*s.* 3*d.* per lb. More than nine-tenths of all the tea brought to the United Kingdom in 1859 entered the port of London; and the preponderance is still increasing. The great increase in the use of tea has not checked that of coffee. The following table shows the average annual consumption of tea, coffee, and cocoa, in the last four decennial periods :

		Tea.	Coffee.	Cocoa.
		lbs.	lbs.	lbs.
Average	1820-29	25,000,000	12,000,000	500,000
	1830-39	34,000,000	24,000,000	1,000,000
	1840-49	41,000,000	33,000,000	2,500,000
	1850-59	63,000,000	35,000,000	3,500,000

Bringing in a more modern article of consumption, chicory, the figures for 1859 were—tea 76 million lbs., coffee, 34 million lbs., chicory, 30 million lbs., and cocoa 3 million lbs. The proportion of black to green tea consumed in the United Kingdom is about 6 or 7 to 1; in the United States the use of green tea is greater than that of black.

TEA, *Medical Properties of.* The botany of tea is given under THEA, in the NATURAL HISTORY DIVISION of this work; its chemical properties are noticed under CAFFEINE; for an account of its culture see TEA AND THE TEA TRADE.

Before attempting to estimate the action of tea on the human system, it is necessary to call to mind that some of the effects are due to the plants mixed with the real tea, several of which, such as the *Chloranthus inconspicuus*, are stimulants of the highest order; and in other instances deleterious chemical compounds are used by the Chinese to convert damaged black teas into saleable green teas. (Davis, ' Chinese,' ii. 466.) For the effects of these, tea is not justly chargeable. A correct estimate of the action of tea is not easily formed; yet the most dispassionate inquirers regard it as a narcotic, the stimulating period of which is the most conspicuous and of longest duration. Tea has been preposterously praised by some writers, and unjustly accused by others as being productive of numerous diseases: above all it has been charged with causing an increase of nervous diseases. It would perhaps be more just to attribute the increase of such complaints to the more complicated state of our social relations, arising from an augmented population, and an advance in luxury, with the more frequent infringement of the natural laws, particularly turning night into day, and not seldom day into night, as is the practice of the votaries of fashion. That tea should not suit all constitutions or all ages is not remarkable. It is less suited for young children than for adults; indeed for very young children it is extremely improper, producing, like all narcotics, a morbid state of the brain and nervous system. It is also unsuited for those of an irritable nature, and likewise for those of a leucophlegmatic constitution. Such persons can ill bear much liquid of any kind, particularly in the evening, and prosper best on a very dry diet, to which growing children of this constitution should be strictly confined. [DILUENTS.] It may not be true that the use of tea, as alleged by Dr. Lettsom, has been the main cause of the increase of scrofulous diseases, still as diseases of this class are the only diseases which are proved by the reports of the registrar-general to be stationary, or perhaps more frequent than others, whatever impairs the nervous power and ultimately the digestive function in strumous children should be avoided. His advice is sound where he says, "It ought by no means to be the common diet of boarding-schools; if it be allowed sometimes as a treat, they should be at the same time informed that the constant use of it would be injurious to their health, strength, and constitution." Those to whom it is most suited are the plethoric and sanguine. Upon the same principle it is a proper article of diet and perhaps the best common drink at the beginning of fevers and inflammatory complaints. In a peculiar state of brain, termed by Mr. Newnham ('Observations on Medical and Dietetical Properties of Green Tea') *sthenic excitement*, a state clearly bordering on inflammation, especially if produced by alcoholic stimulants, or by intense and long-continued application of mind to any particular object of literary research, green tea acts as a salutary remedy. On the contrary, in states of diminished excitement, morbid vigilance and nervous disturbance follow its use. It is not an uncommon practice with ardent students, when pushing their studies far into the night, to resist the claims of nature for repose, and keep themselves awake by the frequent use of tea. That it answers the purpose at the time cannot be denied, but the object is often attained at a fearful price, the destruction of health and vigour both of mind and body being the penalty. But more effect is produced by small doses, frequently repeated, than by large ones. See the paper on the 'Uses of Tea in the healthy System,' read before the Society of Arts, 15th February, 1861, p. 188. Dr. Smith's remarks are based upon a most extensive series of experiments—the results of which are most important. Less injury results in these cases from the use of coffee. There is this difference between the morbid states of the nervous system produced by coffee and those resulting from tea: that the former generally subside or disappear entirely on relinquishing its use; those from the latter are more permanent, and often incapable of being eradicated. Nevertheless many persons have immediately found their health improved by entirely relinquishing the use of tea, or even omitting it only at breakfast, for which meal it is certainly less proper than for the evening beverage. Those for whom tea is unsuited will generally find weak cocoa the most proper substitute.

Persons of a gouty and rheumatic nature, above all, those prone to calculous diseases of the lithic acid diathesis, find weak tea the least objectionable article of common drink. They should take it without sugar, and with very little milk. (Prout, 'On the Stomach,' p. 217.) Where the water is hard, the addition of a little carbonate of soda not only improves the tea, but renders it a more proper beverage for such persons. This addition of an alkali seems to increase the action of tea upon the skin, and to augment its cooling properties. Cream appears to lessen the action on the skin, as does also lemon-juice. (Smith, *ut supra*, p. 189.) Tea should not be used till about four hours after any solid meal.

The medical uses of tea are not many. In fevers it is not only an excellent diluent at the commencement, but a tincture of tea made by macerating tea in proof-spirit, and adding a teaspoonful of this to a small cup of water, and given at short intervals during the night, after the acute symptoms have subsided, is often of great service. For this purpose, in hospitals and workhouses, the leaves which have been used for the ordinary infusion may be macerated in alcohol, and a spirit of sufficient strength for this purpose obtained at a cheap rate.

In some forms of diseased heart tea proves a useful sedative. It is nearly as valuable an antidote to poisoning by opium as coffee is. Some cases of poisoning by arsenic and tartarised antimony have been prevented proving fatal by the immediate administration of tea in the form of a very strong infusion. Here its power as an antidote depends upon its tannin decomposing the poisonous substances. [ASTRINGENTS.] But in poisoning by opium it is useful only in combating the secondary symptoms, and should not be administered till the stomach-pump or other means have removed the opium from the stomach. Some cases of severe nervous headache are relieved by a cup of strong green tea, taken without milk or sugar. But this should be sparingly resorted to; it is a wiser plan to avoid the causes of such headaches. Tea has been looked upon as the great means by which intoxication was to be banished, but it is certain that to relieve the tremblings and other unpleasant effects of the abuse of tea, a little brandy or other alcoholic stimulant is occasionally added to the cup of tea, and so a habit is acquired which can never afterwards be relinquished.

Tea has frequently been denounced as a useless article of diet to the poor, as it is assumed to be devoid of nutriment, and the milk and sugar which are added are supposed to be the only beneficial ingredients. Dr. Lettsom has given a calculation, partly his own, and partly taken from 'Essays on Husbandry,' to show how much is, in his view, unnecessarily expended by them in this way. But the observations of Liebig are thought to offer a satisfactory explanation of the cause of the great partiality of the poor not only for tea, but for tea of an expensive and therefore superior kind:—

"To see how the action of caffeine, asparagine, theobromine, &c., may be explained, we must call to mind that the chief constituent of the bile contains only 3·8 per cent. of nitrogen, of which only the half, or 1·9 per cent., belongs to the taurine. Bile contains in its natural state water and solid matter, in the proportion of 90 parts by weight of the former to 10 of the latter. If we suppose these 10 parts by weight of solid matter to be choleic acid, with 3·87 per cent. of nitrogen, then 100 parts of fresh bile will contain 0·171 parts of nitrogen in the shape of taurine. Now this quantity is contained in 0·6 parts of caffeine; or $2\frac{8}{13}$ths grains of caffeine can give to an ounce of bile the nitrogen it contains in the form of taurine. If an infusion of tea contain no more than the $\frac{1}{10}$th of a grain of caffeine, still, if it contribute in point of fact to the formation of bile, the action, even of such a quantity, cannot be looked upon as a nullity. Neither can it be denied, that in the case of an excess of non-azotised food and a deficiency of motion, which is required to cause the change of matter of the tissues, and thus to yield the nitrogenised product which enters into the composition of the bile; that in such a condition the health may be benefited by the use of compounds which are capable of supplying the place of the nitrogenised substance produced in the healthy state of the body, and essential to the production of an important element of respiration. In a chemical sense—and it is this alone which the preceding remarks are intended to show—caffeine, or theine, asparagine, and theobromine, are, in virtue of their composition, better adapted to this purpose than all other nitrogenised vegetable principles. The action of these substances, in ordinary circumstances, is not obvious, but it unquestionably exists. Tea and coffee were originally met with among nations whose diet is chiefly vegetable." (Liebig's 'Animal Chemistry,' p. 178.) These facts show in what way tea proves to the poor a substitute for animal food, and why females and literary persons who take little exercise manifest such partiality for it. They also explain why the attempts, and they have been numerous, to find among other plants a substitute for tea have invariably failed of success.

TEA, PARAGUAY, or MATÉ. [TEA, PARAGUAY, in NAT. HIST. DIV.]

TEAK, ECONOMICAL USES OF. The teak tree is found in Burmah, in India, and in various islands in the Indian seas. It grows to an immense size, and is remarkable for its very large leaves, which are from 12 to 24 inches long, and from 8 to 16 inches broad. The wood is light, brownish coloured, and easily worked, as well as very strong and durable. It is soon seasoned, and from containing a resinous oil, resists the action of water, as well as that of insects. The density of the wood varies from 0·594 to 0·876, according to its quality and the mode in which it is seasoned; the average is about 0·711. One specimen has been described having a specific gravity of 1·056; but the accuracy of this statement is doubtful. From extensive experience, teak has been found to be the most valuable timber for ship-building. Teak is the principal article of export, both in quantity and value, from Moulmein; near which port are vast forests of the best teak in the world. Splendid baulks of timber are shipped there, 50 feet in length, and as much as 24 inches square. The price of first class teak at that port, squared into baulks, is usually about 60*s.* per ton of 50 cubic feet. At the Great Exhibition of 1851, a very interesting collection was displayed, consisting of more than seventy species of teak, obtained from various localities and arranged according to their density. They were collected by Mr. Seppings of Calcutta, and were contributed by the Naval Department of the East India Company.

TEAM. Nothing is of greater importance in the management of a farm than the cattle which perform the necessary work in ploughing and other operations on the soil, in drawing manure to the land and carrying the produce to market. It is evident that the smaller the expense of the team which does the requisite work in proper time, the greater the profit of the farmer, and every saving in this part of the expense of cultivation is so much added to the clear gain. Wherever the land is only partially cultivated, and a portion of it remains in coarse pasture, which costs little or nothing to the occupier, or where extensive open commons afford cheap food for oxen, these last are naturally employed in farm labour. If four oxen do only the work of two horses, they are maintained at a much smaller expense, and, after working for two or three years, their value is improved for the purpose of fatting for the butcher. The necessary gear is much less expensive, especially where the old yoke is still in use, whether across the neck or the horns. In fact, for a poor man who has only a few acres of land, and who is situated near a waste or common, oxen are the most economical team. Many, who in general have more theoretical than practical knowledge of husbandry, have maintained the general superiority of an ox team over that composed of horses, and have given calculations which appear clearly to establish their point. But on the other side, it may be observed, that wherever arable land is the chief object of the farmer's attention, and the tillage of the soil is brought to any degree of perfection, there oxen are never seen at work, but have been invariably superseded by active horses. Oxen as draught animals are almost invariably part of a sluggish agriculture; and though less costly themselves, yet teaching slow and dilatory movement to everything about them, their use for tillage operations is everywhere diminishing.

As to the cost of horses per annum, the following may suffice. In the old mode of feeding, with as much hay as they would eat, and two bushels of oats for each horse per week, during at least nine months in the year, and giving them tares or artificial grasses between spring sowing and harvest, when there was less to be done, the expense of a horse was much greater than most farmers could now afford; and more land was devoted to the keep of the team than was necessary. The following is the calculation of the cost of the keep of a horse in this way:—

	£	s.
32 weeks, at 2 bushels of oats per week, at 3s. 6d. per bushel	11	4
20 weeks, at 1 bushel of oats per week, at 3s. 6d. per bushel .	3	10
Tares, &c., 20 weeks, at 6s. (1 cwt. daily, at 6d.) . . .	3	10
Hay, 32 weeks, about 1½ cwt. weekly, at 4s. per cwt. . .	9	2
Shoeing	0	15
Farrier	0	5
Total	£28	6

The hay and oats are at high prices, but at all events a horse cannot be kept in this way under 10s. per week. They are then, however, in excellent condition, and able to work ten hours per day in summer and eight in winter.

The use of bruised corn and carrots, and mangold-wurzel and chaff of hay and straw, secures a considerable economy; and taking smith, farrier, harness, and depreciation of value (3*l.* per annum) into account, the cost per horse should not be more than 30*l.* a year. In fact, on 21 farms, the details of which have been given by Mr. Morton in the Agricultural Society's 'Journal,' 282 horses working 8851 arable and 2549 pasture acres, cost 7513*l.* 8*s.* per annum, or about 26*l.* 12*s.* apiece. In this, the wages of team-men had to be added, nearly 13,000*l.*, in order to find the cost of horse-labour per annum.

It is of great importance to a person about to hire a farm to know exactly what number of horses will be required for its proper cultivation, and this depends upon many circumstances, which must all be taken into consideration, and which will make a very material difference, often as much as half the rent of the land. He is to consider the situation of the farm-buildings, especially the stalls and cattle-yards, where the manure is to be made, with respect to their distance from the fields; the state of the roads and the access to the fields; the distance of a good market-town, and whether the fields lie in a ring-fence or are scattered. A farm of good light loam will require one horse for every thirty-five acres for its cultivation. The larger the farm, or rather the fields, the fewer horses are required in proportion to its size, because much time is lost in turning the plough where the furrow is short; and ploughing is always the principal work of the team. If more than two horses are required to plough the ground, the soil must be very compact and heavy, and if this is not compensated by greater fertility, the expense of the horses will much reduce the profit of the farmer. The work in the field when the days are long should be divided so as to give the horses at least two hours' rest, during which they should be fed with corn. When the fields are near the stables the horses may be brought home, but a portable manger is easily carried into the field, such as is used at the inns on the roads where carriers stop to bait. In winter it may be as well to finish the day's work with only an interval of half an hour. The time in summer should be from 5 in the morning till 10, and from 2 till 7 if the weather is very warm, resting four hours; or from 6 till 11 and from 1 till 6, resting two hours. In winter the time is from 7 till 3, resting half an hour or an hour between 11 and 12. With good feeding and grooming this is by no means too hard work when the work requires to be carried on briskly. The heavier and lighter kind of work should be so arranged that when horses have worked hard for a day or two, they may have one or two days of lighter work. In most parts of England the pace of the horses and their daily work are much less than in Scotland; two horses should plough an acre a day or more, on an average, but few farmers can get much more accomplished than three-quarters of an acre, if they plough a good depth or break up clover or grass lays. In the light sands of Norfolk and Lincolnshire they go over much ground; but there the furrows are wide and shallow, and the horses might easily trot with the plough if the ploughman could keep up with them.

TEAZLE (*Dípsacus Fullónum*) is a plant which grows wild in the hedges, but an improved variety is carefully cultivated in those districts of England where cloth is manufactured. It is used for the purpose of forming a species of brush with which the finer hairs of the woollen fabric are drawn to the surface, where they produce what is usually called the *nap* of the cloth. Several attempts have been made to substitute artificial teazles, formed of hooks of very fine and elastic steel wire; and at one time there was so much appearance of success, as to cause the cultivation of teazles to be neglected: but it was soon found that the wires tore the fine fibres of the wool, especially where there were knots in the thread, whereas the hooks of the teazles gave way, and either bent or broke off before the fibre of the wool was injured.

Teazles grow strongest and best in a stiff loam. They require the soil to be in good heart, and are supposed to exhaust it much; but no great portion of manure is required to obtain a good crop. The growing of teazles is a peculiar trade. The teazle-grower hires a piece of ground suited to his purpose from the farmer for two years, and pays a considerable rent. If the ground is broken up from grass, it is ploughed as deep as the staple of the soil permits, and as early as possible, if before winter so much the better: the ground is laid in narrow stitches, on which the seed is sown in April, in rows from 12 to 18 inches apart: moisture is necessary to make the seed germinate. As soon as the plants appear, they are thinned out, and the intervals carefully hoed and weeded. During the summer, the ground is several times dug, or *spaded*, as it is called, to a considerable depth, with very narrow and long spades; this greatly invigorates the plants. In November, plants may be transplanted from where they stand too thick to the places where they have failed, and also to other land cultivated for the crop. They should stand about a foot apart in the rows. During the ensuing spring, the cultivation is repeated. They soon begin to push up their stems, and are fit to be cut in July, just when the blossom has fallen. As they do not come to proper maturity at the same time, several successive gatherings are made. They are cut with a sharp knife about nine inches below the head, and tied in small bundles or handfuls: thick gloves are very necessary in this operation. They must be carried under cover before night, as the rains or heavy dews would injure them. When the sun shines, they are exposed to dry in the same manner as is done with onion seed, and they are never packed close until they are perfectly dry. When drying they are usually hung on poles; so that the air may circulate between the bundles. The bundles are afterwards opened, and the teazles sorted into kings, middlings and scrubs, according to their size; 9000 kings or 20,000 middlings make a pack.

Teazles are a very precarious crop; sometimes they produce a very great profit, and at other times a serious loss. Care and cultivation lessen the chances of failure greatly: but the price also fluctuates so much that it is an uncertain speculation, resembling in this respect the cultivation of hops. Hence it is undertaken by men who are prepared for the event, and who make the profits of one year repay the loss of another. A good crop of teazles is about 10 or 12 packs on an acre: this is sometimes exceeded, but more often it fails by one-half, and a total failure is not uncommon. The price may average 5*l.* or 6*l.* a pack, so that a good crop is worth more than the land it grew on; the expenses, however, are large. Although teazles are said to exhaust the ground much, yet from the continual stirring of the soil they render it very fit to grow other crops, provided a proper quantity of manure is used: thus very good crops of wheat have been obtained after a crop of teazles.

TEETH, DISEASES OF THE. The teeth, like other organs of the body, are subject to a variety of diseased conditions. For practical purposes they may be divided into—1. Disorders attending dentition or the cutting of the teeth; 2. Diseases of the teeth themselves; 3. Diseases of the gums and alveolar processes.

Diseases of Dentition.—The eruption of the temporary or milk-teeth is a natural process after birth [Dentition, Diseases of; and Teeth, Nat. Hist. Div.]. The order in which the milk-teeth appear after birth is subject to considerable variations. Although dentition is a natural process, it is frequently attended with morbid conditions. Prior to the appearance of a tooth the gum above it increases in breadth, becomes swollen, and is hot to the touch. There is an increased flow of saliva, which comes out of the mouth; the child thrusts whatever may be placed in its hands into its mouth. It is more fretful than usual, has sudden fits of crying, and starts in its sleep. The cheeks are flushed, the bowels are irregular, and its food is often thrown off its stomach. It not unfrequently happens that a dry cough is present, and sometimes even severe derangement of the nervous system.

In the *treatment* of these symptoms little more is needed than to regulate the state of the bowels, and to prevent the child overloading its stomach with milk. It should not be put to the breast after every time it is sick, but cows' milk, with a little water and sugar, may be substituted for its mother's milk. When convulsions occur and evidently arise from the irritation of the gums, a free incision of the gum over the pressing tooth will often give great and immediate relief. Whenever in fact the irritation has proceeded so far as to produce obvious inflammatory symptoms, recourse may be had to lancing the gums. In this operation care should always be taken to divide the gum down to the surface of the pressing tooth.

Sometimes instead of inflammation of the jaws there is an excessive hardness or induration of the gums. In this case there is great irritability and restlessness, with other symptoms of derangement of the system, which can only be removed by dividing the indurated gums freely down to the pressing tooth.

During the presence of the milk-teeth, they and the gums are subject to the same diseases as the permanent teeth in after life. They are however subject to one form of disease which is peculiar to children, and which is called *ancrum oris*. It is in fact an ulceration attended with a death of parts similar to what is called phagædena in other organs of the body. The ulceration commences in this case at the free edge of the gums and extends to the alveoli and other parts of the mouth. The surface of the cheek lying in contact with the ulcerated gums becomes involved in the same disease, so that the surfaces of the two ulcers are in contact. The teeth loosen and in some cases become black from necrosis. The surface of the ulcer is of a pale yellow or straw colour, with here and there a red point raised above the surface, and which bleeds on being touched. This disease spreads in some cases till the cheek is perforated, but it more frequently happens before this takes place that the patient either sinks from exhaustion or hæmorrhage from the ulceration of some large vessel.

The treatment in these cases must be both constitutional and local. The bowels should be kept open, and tonic medicines (iron and quinine), with a liberal diet, must be given. Locally, the nitrate of silver should be applied, and the mouth should be washed out with a lotion containing chlorate of potash. This latter salt has also been strongly recommended as an internal remedy.

The milk-teeth disappear as they came, at various ages. They are succeeded by what are called the permanent teeth. The number of these is thirty-two. Twelve of them, however, belong to the first set, as they are never superseded. So that the true view of the case appears to be, that the first set of teeth consists of thirty-two, of which twenty disappear under the name of milk-teeth, and are followed by twenty others, which are called, with the other twelve, permanent teeth.

Diseases of the Permanent Teeth.—The diseases to which the permanent teeth are subject have been arranged as follows by Mr. Tomes:—

Irregularity in the time of the eruption of the permanent teeth.	
Irregularity in the position of the permanent teeth.	
Mechanical injuries of the teeth . .	**Fracture.** **Dilaceration.** **Dislocation.**
Mechanical injuries of the alveoli . . .	**Fracture.**
Diseases of the dental tissues . . .	**Caries.** **Necrosis.** **Exostosis.** **Abscess.** **Loss from the surface.** **Absorption.** **Pain.**
Diseases of the pulp	**Irritation.** **Inflammation.** **Ulceration.** **Granulation.**
Diseases of the alveolar periosteum . .	**Inflammation.** **Hæmorrhage.**
Diseases of the alveoli	**Inflammation.** **Necrosis.** **Exostosis.** **Absorption.**
Diseases of the gums	**Inflammation.** **Ulceration.** **Recedence.** **Tumours.** **Epulis.** **Polypus.** **Vascular tumours.** **Blue gum.**
Tartar.	

It will be unnecessary here to refer in detail to these disorders of the teeth and gums, as many of them are common to these tissues with other parts of the body, and require the same general treatment. We shall therefore refer more particularly to those disordered conditions of the teeth and gums which produce the complaints known under the name of toothache and faceache, and the other more frequent disorders of these organs.

Dental Caries.—One of the most frequent causes of pain in the teeth is that destructive process known by the name of caries. Various views have been taken of the nature of this process; but Mr. Tomes defines it as "the death and subsequent progressive decomposition of a part or the whole of a tooth." The changes which indicate the occurrence of this condition are, first, a discoloration of the dental tissue, which is succeeded by softening and disintegration. The enamel first suffers, and then the dentine. The disease spreads in the direction of the dentinal tubes down to the pulp, forming a conical cavity with an oblique direction. It is not, however, infrequent to find the hole in the enamel less than that in the dentine, as the process of decay goes on much more rapidly in the latter than in the former.

This process of decay may or may not be attended with pain from the time of its first setting in. Eventually, however, the caries extends to the pulp cavity where the nerves are situated, and pain is the result. Even this is sometimes prevented by a kind of reparative process going on in the dentine, which forms the walls of the cavity, and which prevents the nerves from being affected.

If the caries extends, the pulp may become inflamed, and also the dental periosteum, which may be followed by alveolar abscess. Before inflammation of the pulp is established, the pain from the tooth becomes intolerable by *irritation* in the pulp. This state comes on gradually: first a little pain is felt when hot or cold or sweet or acid things are put into the mouth. This goes on increasing till inflammation is established in the pulp of the diseased tooth. This frequently leads to irritation in the pulp of the sound teeth, so that pain may be felt in several teeth by the unsoundness of one.

It is when the pulp becomes inflamed that the violent throbbing pain known as toothache comes on. In this state a destruction of the pulp may take place and the pain cease, and the tooth retaining its vitality from its external periosteum alone may still be useful. This is, however, a very rare occurrence.

In the treatment of caries of the tooth, and its attendant irritation and inflammation of the pulp, it should be recollected that all external remedies are palliatives. A natural cure, which is very unlikely, may go on whilst a little relief is obtained by such applications as opium, ether, creasote, alum, chloroform, tannic acid, nitrate of silver. The multitude of remedies for toothache show how utterly intractable a disease it is, and how little amenable to anything like external treatment. Nor will internal remedies affect the tooth, or in any manner arrest the caries which produces the pain.

If caries is observed in the early stages, before the pulp cavity is affected, then the diseased part may be scooped out, and the cavity plugged up in various ways. This, however, must be done early, in order to ensure success. It not unfrequently happens that where irritation of the pulp cavity has been set up plugging will relieve. Where irritation is set up in neighbouring teeth from inflamed pulp, then the removal of the offending tooth is immediately atteuded with relief to the others.

In the case of inflammation of the pulp, where the pain is severe, the tooth should be removed. The hazard of ulterior consequences to the alveolar process and the jaw should always prompt to the removal of the inflamed tooth.

The consequences of decay of the teeth are not at all confined to the simple pain called toothache. The inflammation may extend from the tooth to the gums, and from the gums to the surrounding structures, so that inflammation of the submaxillary glands takes place, and a swelling of the whole face occurs. Such inflammation may be acute or chronic. When it is acute it may subside in a few days after the application of the ordinary remedies for an acute inflammatory condition of the soft tissues. It may, however, be chronic, and attended with ulceration of the mucous membrane, which may extend to the throat. In these cases local remedies may relieve. The application of tannic acid, alum, or chlorate of potash will be of service, but the great remedy of all is the removal of the cause—the extraction of the decayed tooth or teeth.

Again, the nervous system may be the seat of the engendered disease. The whole of the nerves of the face singly or together may be the seat of reflected pain from the inflamed pulp of a single tooth. These pains, often taken for idiopathic neuralgia, cannot be effectually relieved till the cause of their excitement is removed. The reflected irritation of the nerves may not only affect nerves, but even the brain itself and the organs of the senses. All obscure pains of the head and affections of the senses should be examined in relation to the condition of the teeth, as a source of irritation not indicated necessarily by pain in the tooth may be frequently found in its disorganised and decayed condition.

The other forms of disease of the teeth are less common and special than those we have spoken of above. Sometimes excessive pain is suffered from *inflammation of the dental periosteum*. When there is no decay of the tooth, and the pain is clearly referable to this cause, much good may be done by the application of one or two leeches to the gum opposite the end of the root of the affected tooth. Antiphlogistic remedies should also be generally applied. Where morbid growths are the result of such inflammation, the extraction of the tooth will be of service; but even then the inflammation may continue in the socket. Sometimes the inflammation is of a rheumatic character, and demands a treatment adapted to this state of the system.

Diseases of the Alveoli and Gums.—From the periosteum we pass on to the alveoli and gums. The diseases of the alveoli which are most frequent are absorption and hæmorrhage.

Absorption of the alveoli frequently takes place as the result of constitutional tendency, and a disposition to this malady is handed down from father to son. Under these circumstances it is not an unusual thing to observe a man under fifty with scarcely any teeth in his head. This process takes place slowly, and almost imperceptibly, till the teeth drop out one after another. Absorption of the alveoli may also be induced by inflammation of the gums, which may be kept up by decayed teeth. The salivation attendant upon the administration of mercury is also accompanied with an absorption of the alveolar processes and a falling out of the teeth.

In the treatment of these cases the great thing is to remove the cause. Where decayed teeth, inflammation of the gums from tartar, or irregular teeth, are present, these must be removed. Nothing seems to arrest the hereditary absorption of the alveoli. It is like the loss of hair, or other defect, an accompaniment of old age, and in certain cases these symptoms come on prematurely. The great resource and comfort of the sufferer in these cases is the introduction of artificial teeth. The manufacture of these organs has been carried to such perfection that little or no inconvenience is felt from their presence in the mouth, whilst they perform the functions of mastication and give the necessary modulation to the voice as though they were the original teeth. They have even this advantage over natural teeth, that they never ache.

Hæmorrhage from the periosteum of the alveoli is not unfrequently a source of alarm, and cases are recorded in which death has occurred from this cause. It usually comes on after the extraction of a tooth. Under ordinary cirumstances the socket becomes filled with a coagulum of blood, which arrests all further bleeding; but in these cases the blood continues to be poured out from the wounded vessels, and resists all attempts at arrest. The best method of treating these cases is to plug the socket with a piece of lint dipped in some strong styptic. One of the most efficient styptics for these cases is the matico, which should be powdered and applied on the outside of a plug of moistened lint.

Inflammation of the Gums.—This may be either acute or chronic, and may come on independent of caries of the tooth or other disease. Acute inflammation is most frequently seen as the result of taking mercury. [MERCURY, *Medical Properties of.*] Chronic inflammation attended with ulceration of the gums is very frequent. It may arise from diseased conditions of the teeth, or from a disordered state of the system. In inflammation without ulceration stimulant applications are very beneficial, whilst the ulcers may be touched with nitric acid, or painted with a strong solution of chlorate of potash.

Blue Gum.—When lead is introduced into the system in small quantities for a length of time, its presence in the system is indicated by a blue or purplish line running along the edges of the gums just where they meet the teeth. This curious fact, which was first pointed out by Dr. Burton, has since been confirmed in a large number of cases. The blue line is, however, only seen in cases where tartar has accumulated on the teeth. It is not seen in cases either where there are no teeth in the gums. Wherever present it indicates the action of lead on the system, and should lead to the investigation of the circumstances under which the patient has received this substance into the system. Mr. Tomes has mentioned two cases in which the same kind of discoloration has taken place from the action of mercury on the system. It is not, however, impossible that the preparations of mercury taken in these cases contained lead.

Tartar.—The saliva which is poured into the mouth contains certain earthy matters in solution, which are precipitated on the roots of the teeth at the point where they are covered by the gums. This precipitate, which is a true salivary calculus, is called "tartar." When chemically examined it has been found to contain in 100 parts—

Earthy phosphates	79·0
Salivary mucus	12·5
Ptyalin	1·0
Animal matter	7·5
	100·0

It assumes a variety of colours on the teeth, according to the nature of the food habitually taken. The accumulation of this substance on the teeth tends to produce inflammation of the gums and to cause their absorption as well as that of the alveolar processes.

When tartar has accumulated to a considerable extent it should be scaled off the teeth by means of instruments fitted for the purpose. One of the great objects of the daily brushing of the teeth is the prevention of the accumulation of this tartar. One of the best dentifrices for habitual use is the camphorated tooth-powder, which consists of camphor carefully powdered and mixed with chalk. All agents that would dissolve the tartar would dissolve the teeth, and must therefore be carefully avoided.

(Tomes, *Lectures on Dental Physiology*; Tomes, *Manual of Dental Surgery*.)

TEETH OF WHEELS. [WHEELS.]

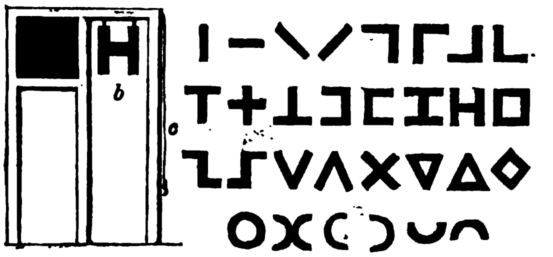
TEKORETIN (C_2H_4?). A native crystalline resin found in the peat of Denmark.

TELEGRAPH (from τῆλε, "distant," and γράφω, "write"), a machine or process for communicating intelligence to a distance, usually by means of preconcerted signals, to which some conventional meaning is attached. The name *semaphore* (from σῆμα, "a sign," and φέρω, "bear"), was also applied to some of the machines used for effecting telegraphic communication; which, in an extended sense, may be considered to embrace every means of conveying intelligence by gestures and visible signals, as flags, lanterns, rockets, blue-lights, beacon-fires, &c., or by audible signals, as the firing of guns, the blowing of trumpets, the beating of drums or gongs, &c., as well as by the machines specially provided for the purpose.

Although telegraphic communication, as a means of conveying *any* required intelligence, is an invention of recent date, the use of signals for the speedy transmission of such brief messages as might be previously arranged between persons, is a practice derived from the most remote antiquity. The use of beacon-fires, for example, as a means of giving speedy warning of the approach of an enemy, is alluded to by the prophet Jeremiah, who wrote about six centuries before the Christian era, and who warns the Benjamites to "set up a sign of fire in Beth-haccerem; for evil," he adds, "appeareth out of the north, and great destruction." (Jeremiah, vi. 1.) The fine description given by Æschylus, in his 'Agamemnon,' of the application of a line of fire-signals to communicate the intelligence of the fall of Troy, is often referred to as an early instance of this kind of telegraphic despatch. This simple means of spreading an alarm, or communicating intelligence, is described by Scott in the 'Lay of the Last Minstrel;' and in a note he refers to an Act of the Scottish parliament in 1455, c. 48, which directs that one bale or faggot shall be warning of the approach of the English in any manner; two bales, that they are *coming indeed;* and four bales blazing beside each other, that the enemy are in great force. Such signals, though best adapted to give information by night, were also available in the daytime, when they appeared as columns of dense smoke. Torches held in the hand and moved in any particular manner, or alternately displayed and hidden behind a screen, were also used in ancient times as signals. Polybius describes two somewhat complicated methods of telegraphing by means of torches; and Bishop Wilkins, in his curious work entitled 'Mercury; or the Secret and Swift Messenger,' after describing this telegraph of Polybius, mentions another which requires only three lights or torches to indicate the twenty-four necessary letters of the alphabet, which are, according to this plan, which he gives on the authority of Joachimus Fortius, to be divided into three classes of eight letters each. The first class is represented by one torch, the second by two, and the third by three; and the number of the letter by the number of times which the torches are elevated or discovered. Similar to this, is the night-telegraph contrived by the Rev. James Bremner, of the Shetland Islands, and rewarded by the Society of Arts in 1816. ('Soc. Trans., xxxiv.) A single light constitutes the whole apparatus, and the whole operation consists in its alternate exhibition and concealment. This plan had been found suitable for distances of twenty miles and upwards, and had been successfully put in operation between the lighthouse on Copeland Island and Port Patrick on the opposite side of the Irish Channel. Bishop Wilkins also describes a method which depends upon the relative positions of two lights attached to long poles, and which, he says, "for its quickness and speed is much to be preferred before any of the rest." This plan came very near to the principle upon which some of the subsequent telegraphic systems depended. In suggesting the use of extended lines of telegraphic communication, he further hints at the application of the telescope (or, as he styles it, 'Galileus his perspective'), to the deciphering of distant signals.

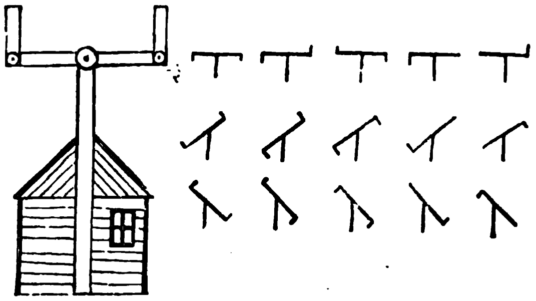
Other writers, such as Kircher, Schottus, and Kessler, have published plans for telegraphic signals. Kessler proposed to cut out such characters as it was desired to show in the ends of a cask, which was to be elevated with a light enclosed in it. The Marquess of Worcester also, in his 'Century of Inventions,' 1663, announces, "How at a window, as far as the eye can discover black from white, a man may hold discourse with his correspondent, without noise made or notice taken," &c.; and again, "A way to do it by night as well as by day, though as dark as pitch is black." But the earliest well-defined plan of telegraphic communication appears to be that described in a paper addressed to the Royal Society in 1684, by Dr. Robert Hooke, and published in 1726 in Derham's collection of his 'Philosophical Experiments and Observations,' pp. 142-150, "showing a way how to communicate one's mind at great distances." Hooke's scheme will be understood by referring to *fig.* 1, which represents an elevated frame-work supporting a panel or screen, *a*, behind which were to be suspended a number of symbols or devices, formed of deal plank, of the various shapes represented by the small black figures. The first twenty-four of these, which consist entirely of straight lines, were to stand for alphabetic characters; and the six devices consisting of curved lines were to be used as arbitrary signals. Whenever it was desired to display any of these characters, they were to be drawn from behind the screen by a rope *c*, passing over pulleys in the frame-work, and so rendered visible in the open space at *b*. These telegraphs were to be erected upon elevated stations, and telescopes were to be used by the observers. The order of connection between the signs employed and the letters of the alphabet might, it is explained, be infinitely varied, for the sake of secrecy; and none of the parties employed, excepting those at the terminal stations, need have any knowledge of the message communicated. Hooke further proposed a scheme for night communication by means of lights disposed in a certain order

Fig. 1.



About twenty years after the date of Hooke's paper, Amontons brought forward a similar plan in France. Some other individuals subsequently devised similar schemes, but nothing was effected in the practical application of telegraphic communication until the wars of the French revolution. Macdonald states that, "Following the principles laid down by Dr. Hooke, in 1684, Dupuis, in France, invented the French telegraph, which Don Gualtier, a monk of the order of Citeaux, in 1781, modified, and proposed to Condorcet, Milli, and Dr. Franklin, who recommended it to the French government." The telegraph brought into use in 1793 or 1794, by M. Chappe, was, as will be seen by *fig.* 2, a very superior machine to that of Dr. Hooke.

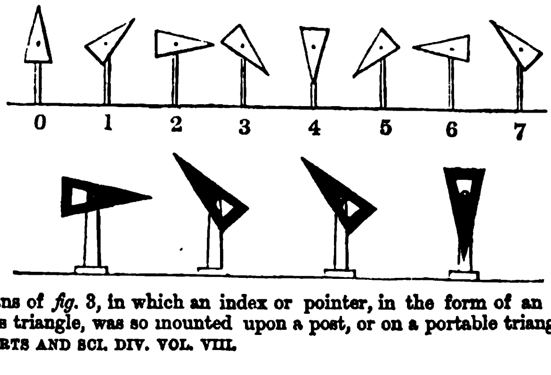
Fig. 2.



Chappe's telegraph, which, from its position when at rest, is sometimes called the T telegraph, consisted of an upright pole or post, at the top of which was pivoted, by its centre, a transverse beam, which, by means of ropes worked in the chamber below, that served also for an observatory, might be made to assume any required angle with the post. Each end of this moveable beam carried a short arm, that was capable of assuming any required angle with it; and these arms also were worked by ropes, which were conducted through the axis of the beam, in order that the necessary degree of tension might not be disturbed by the action of the machine. By this contrivance, without the use of any angles of less than 45° (which might be indistinct when viewed from a great distance, or under the influence of a refractive atmosphere), as many as 256 different signs might be made. A much smaller number was however sufficient, as M. Chappe communicated his intelligence letter by letter, and simplified the movements by using an alphabet of only sixteen letters. The small figures in the cut show some of the different positions assumed by the beam and arms; and, as the connection between these and the letters they were made to represent, was quite arbitrary, their signification might be changed as often as was necessary for the purposes of secrecy; it being only necessary that the key should be known to the parties sending and receiving the message, although it might be transmitted through a great number of intermediate stations. Such telegraphs were first erected on a line commencing at the Louvre, in Paris, and proceeding by Montmartre and other elevated points to Lisle, in order to communicate between the Committee of Public Welfare and the combined armies in the Low Countries. Telescopes were used at each station, and the signals displayed at one station were immediately repeated at the next; four seconds being found sufficient for effecting the required motions, and sixteen seconds the time allowed for observing and noting down each signal, during which the machine remained stationary. Barrère, in announcing the invention of the telegraph to the Convention, on the 17th of August, 1794, stated that the news of the recapture of Lisle had, by means of this machine, reached Paris in an hour after the troops of the Republic had entered the place. ('Annual Register,' 1794.)

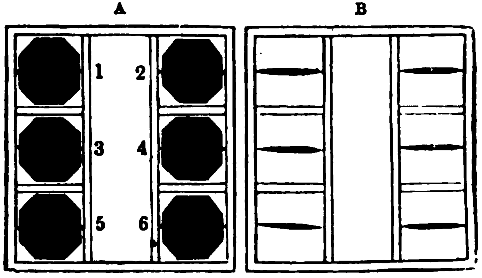
The advantages of such extraordinary celerity of communication were so obvious, that in England and other countries many plans were immediately brought forward, some of which differed materially from that which had been successfully put in practice in France. Among these was that contrived by Mr. R. L. Edgeworth, whose numerical telegraph (or a telegraph expressing numbers, which numbers refer to letters, words, or sentences, in a dictionary), will be understood by means of *fig.* 3, in which an index or pointer, in the form of an isosceles triangle, was so mounted upon a post, or on a portable triangular stand, that it might be turned into any of the eight positions shown in the upper part of the cut; these positions indicating, respectively, 0 and the numerals 1 to 7. Four such pointers, mounted side by side, as in the lower part of the figure, afford power for expressing any number from 1 to 7777, excepting 8, 9, 18, 19, 28, 29, and all others in which the numerals 8 and 9 are required: the first pointer representing thousands, the second hundreds, the third tens, and the fourth units. Thus, the four black pointers in the figure being, respectively, in the positions indicating 2, 7, 7, and 4, express, collectively, the number 2774. Further particulars of this method will be found in Edgeworth's 'Essay on the Art of Conveying Secret and Swift Intelligence,' published in the sixth volume of the 'Transactions of the Royal Irish Academy.' He also published a pamphlet entitled 'A Letter to the Right Honourable the Earl of Charlemont on the Tellograph, and on the Defence of Ireland,' which was reprinted at London in 1797.

Fig. 3.



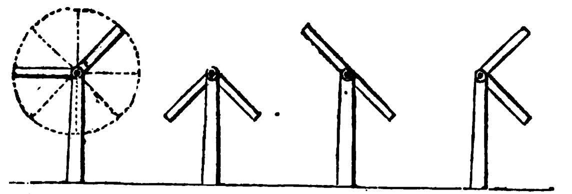
The Rev. J. Gamble, chaplain to the Duke of York, proposed a shutter telegraph, consisting of a frame-work containing five boards, or shutters, arranged vertically one above the other, and pivoted in such a way that any or all of them might be closed, so as to present their broad surfaces to the eye, or opened, so as to show merely a thin edge, which would be invisible at a distance. The various signals produced by closing one or more of these shutters may be applied either to a numerical or an alphabetical system. A similar plan submitted to the Admiralty in 1795, by Lord George Murray, was adopted in the first government line of telegraphs established in England, in 1796, between London and Dover. The 'Annual Register' for that year (p. 4 of the 'Chronicle') mentions the erection of the telegraph over the Admiralty on the 28th of January, and states that information had been conveyed from Dover to London in seven minutes. The action of this kind of telegraph, which was continued in use by the Admiralty until the year 1816, is illustrated by *fig.* 4, in which A represents a square frame-work with six octagonal shutters, 1, 2, 3, 4, 5, and 6, arranged in two vertical columns, or sets, and turned into a vertical position, so as to display their broad surfaces completely, and B represents the same apparatus with the boards or shutters placed horizontally, or turned one-quarter round upon their respective axes, so as to present nothing but their edges to the eye. The central space between the two columns of shutters serves to render them more distinct to a distant observer, and affords room for the ropes and pulleys by which the telegraph is worked, and which are managed by persons in the observatory below. A modification of this kind of telegraph, intended for night as well as for day service, was submitted to the Society of Arts, in 1805, by Mr. Joseph Davis. About the same time that shutter-telegraphs were being introduced in England, the Chevalier A.ᵉ N. Edelcrantz, of Stockholm, was devising similar machinery for use in Sweden. (See Nicholson's 'Journal,' 1803; Society of Arts 'Transactions' for 1808.) Other modifications of the shutter telegraph were put forward from time to time, but experience established the superiority of telegraphs or semaphores with moveable arms; and these were greatly simplified, so as to avoid the objection raised to the old French telegraph. Among the schemes proposed soon after the first practical application of telegraphs, was one which consisted in dividing a large circle into twenty-four parts, for the letters of the alphabet, and employing a traversing radius, or index, to point them out; wires being fixed before the object-glass of the telescope to enable the distant observer to determine the position of the radius. This plan could only be applied to short distances, because refraction might render it difficult to distinguish between positions so little varying from each other. The same radiating principle was, however, adopted in some machines of a more practical character; among which was a telegraph contrived by the Rev. J. Gamble, consisting of five beams or arms pivoted at the top of a post, upon one axis, and capable of producing many different combinations without using angles of less than 45°. On a similar principle were constructed the French coast telegraphs adopted in 1803, to which the name of *semaphore* was first applied, and from which it has been given to other telegraphic machines, the action of which is dependent upon the motion of arms around pivots placed at or near their extremities. These French semaphores, or, as they were sometimes called, *signal-posts*, consisted of upright posts with two or three moveable arms, turning upon separate pivots, one above the other. Before they were much known in this country, Captain Pasley had been led to observe the inferiority of the common land-telegraph to that used at sea, which consisted of coloured flags.

Fig. 4.



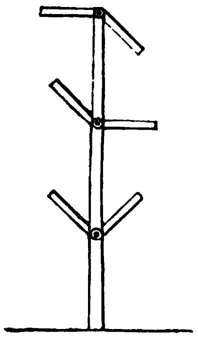
and by which three numbers, or rather three numerals combined to form one number, might be readily expressed. To remedy this defect, he, in 1807 (before he had seen the French semaphore), devised what he termed a "polygrammatic telegraph," a description of which was published in Tilloch's 'Philosophical Magazine,' vol. xxix. This machine, *fig.* 5, consisted of four posts, at the top of each of which was pivoted a pair of arms. Each pair of arms was capable, by assuming the various positions indicated by the dotted lines added to the first pair, of forming more than a sufficient variety of distinct signals to express any of the numerals or the 0; and consequently the whole machine could represent any number composed of not more than four figures, besides having several signals to spare.

Fig. 5.



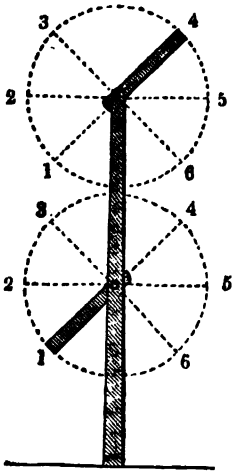
In 1809 Captain Pasley saw the French semaphore, which he described in the following year, together with a modification of his own polygrammatic telegraph, founded upon it, in the thirty-fifth volume of the periodical just mentioned. This simplified polygrammatic telegraph, represented in *fig.* 6, has three pairs of arms, representing hundreds, tens, and units, pivoted to different parts of the same vertical post. This contrivance is adopted by Lieutenant-Colonel Macdonald, with very trifling variation, in his 'Treatise explanatory of a new System of Naval, Military, and Political Telegraphic Communication,' published in 1817. By the addition of a ball and a vane at the top of the mast, it becomes a machine of the same power as Macdonald's thirteen-shutter telegraph; as each pair of arms is capable of assuming fifteen distinct positions. Another semaphore on the same principle was submitted to the Society of Arts in 1821, by Lieutenant N. H. Nicolas, and described, together with a method of applying a shifting key to telegraphic communications, for the purpose of insuring their secrecy, in the thirty-ninth volume of the Society's 'Transactions.' The telegraphs upon the commercial line of communication established between London and the Downs were constructed upon another modification of the polygrammatic principle; four pairs of arms being employed, but mounted upon two posts instead of one, as in Nicolas's semaphore, or four, as in the original design of Captain Pasley.

Fig. 6.



In 1816 it was determined to change the Admiralty telegraphs into semaphores constructed on the principle of those used in France, with the improvements suggested by Sir Home Popham, who had previously done much for the improvement of naval signals. The action of Popham's semaphore is explained by *fig.* 7, in which dotted lines are added to show the various positions in which the arms may be placed, and numerals to show the numbers indicated by those positions. Only two arms are employed; but as they are mounted upon separate pivots, each of them can assume six different positions, and the two together are capable of affording forty-eight signals; which number, though less than that given by the six-shutter telegraph, is sufficient to express the letters of the alphabet and the Arabic numerals, and to leave thirteen signals unappropriated, for abbreviations and arbitrary signs. This kind of semaphore (which is minutely described in the 'Society of Arts Transactions,' vol. xxxiv.) was used at the government stations until superseded by the electric telegraph.

Fig. 7.



The vertical post of this telegraph was a hollow hexagonal mast, which, turning on a pivot at its foot, and in a collar where it passed through the roof of the observatory, could be moved so as to display its signals in any direction. The moveable arms were provided with balance-weights in the form of masses of metal attached to their shorter ends, very near to the pivots upon which they turned, by which means they could be moved in any direction with the exertion of a very small force; and they were made, when out of use, to fall into grooves or recesses in the post, so as to become invisible. The movements were effected by means of two winch-handles near the base of the mast, within the cabin, one for each arm. The winch-handles turned two small bevel-wheels, which communicated motion by means of two horizontal bevel-wheels to long upright shafts or rods, which passed up the inside of the hollow post of the telegraph. At the upper ends of these rods, which were held steady by suitable bearings, were endless screws, working into toothed wheels fixed upon the axes of the arms, and thereby communicating motion to them. In order that the person who worked the machine might know precisely when the arms were brought to the required positions, similar endless screws were added near the lower ends of the vertical rods, to give motion by toothed wheels to indexes, which gave a miniature representation of the motion of the arms. Excepting these indexes and the winch-handles, the whole apparatus was inclosed in the vertical shaft of the telegraph, on the outside of which small blocks were added, to enable a man, with the assistance of a rope from the top of the post, to ascend the machine for the purpose of cleaning and oiling it.

About the same time, Sir Home Popham proposed a modification of the semaphore for marine purposes, which, he conceived, would be found very advantageous for the merchant-service, by superseding the necessity for a costly set of signal-flags, the expense and wear and tear of which formed a serious objection to a system of general telegraphic communication at sea, excepting in the ships of the East India Company. His proposed sea-telegraph would not, it is stated, cost more than fifty shillings at first, and its wear and tear would not amount to five shillings a year. As the height of an apparatus resembling the land-semaphore would be objectionable for marine purposes, Popham proposed to use two posts, 12 feet 2 inches high and 6 inches thick, each having a single arm, 6 feet 4 inches long and 10 inches broad, pivoted to the top, but not falling into a slot in the post, as in the last-described machine. In a small slot at the top of each post is a grooved pulley or sheave, fixed upon the same axis as the arm; and at a convenient height from the bottom of each post another precisely similar pulley is mounted in like way, its axis passing through the post, and carrying a small wheel with four handles at right angles with each other, by which the machine is worked; the motion of the lower pulley being communicated to the upper one, and consequently to the arm, by an endless rope, which has two or three turns round each of the sheaves, and passes up by the sides of the post. When the telegraph is in use, the posts may be attached to the sides of a vessel by stepping their lower ends into blocks fixed for the purpose, and lashing them to the bulwarks; or they may be mounted upon trucks, so as to be readily moved from one part of the ship to another. The description of this machine in Sir Home Popham's communication to the Society of Arts mentions but four positions for each arm, and states that when placed in the four positions diagonally to the post, one arm denotes 1, 2, 3, and 4, and the other 5, 6, 7, and 8. This arrangement gives twenty-four distinct signals, and avoids the possibility of mistaking the horizontal for an inclined position of either arm, of which there might, owing to the motion of the ship, be some risk.

Major-General Pasley, in a pamphlet published in 1823, entitled 'Description of the Universal Telegraph for Day and Night Signals,' abandons the polygrammatic principle, and adopts the simple form shown in *fig.* 8, which represents what he styles the "universal telegraph," as adapted for day-service. It consists of an upright post with two arms, both attached to one pivot at its upper extremity. Each arm is capable of assuming the seven positions indicated in the cut, besides what is called the *stop*, which is made when turned down and obscured by the post. Twenty-eight distinct signals may therefore be made by the apparatus, as shown in the subjoined table; these being more than sufficient for the letters of the alphabet, though not numerous enough to allow of a full alphabet and the numeral characters.

Fig. 8.

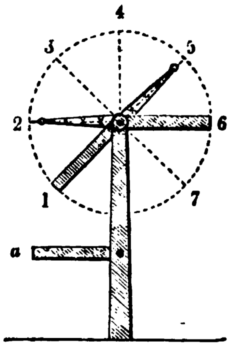


Table of the separate or distinct Signals given by Pasley's Universal Telegraph.

1	6	15	25	36	56
2	7	16	26	37	57
3	12	17	27	45	67
4	13	23	34	46	
5	14	24	35	47	

It had been found, in using Sir Home Popham's ship-semaphores that uncertainty was occasioned by the signals being sometimes seen in reverse, in which case one number or sign would be confounded with another; Pasley provided against this occurrence with his universal telegraph by the addition of the auxiliary arm, or indicator, marked *a*, *fig.* 8, which, in whatever direction the machine may be viewed, distinguishes the side at which the numeral signs commence. It serves also to prevent the position marked 4 from being confounded with the stop, which it might be if there were nothing to indicate that the telegraph is at work, and to enable the eye to measure its height. The counterbalance weights of the arms are not fixed close to the pivot, but extend to some distance from it, in the form of a slender framework of iron, with a ball at the outer extremity, their light appearance rendering them almost invisible at a distance. Pasley states that telegraphs should in general be painted black, and, if possible, so placed that they may be seen without any background. If, however, a background be unavoidable, the telegragh should be of such a colour as to contrast with it. In some cases, where the appearance of the background varies much at different periods of the day, it has been found useful to paint the arms white and black, in large chequers, each occupying half of the width and half of the length of the arm.

The contrivances which have been suggested for effecting telegraphic communication are so very numerous, that anything like an enumeration of them is impossible in this place. Several depend upon the application of arms of various forms to a semaphoric telegraph, while another class of telegraphic contrivances depend upon the exhibition of devices or symbols, in a manner somewhat resembling the original contrivance of Dr. Hooke. In Mr. Spencer's 'anthropo-telegraph,' a man holds a couple of discs in his hands, and makes signals by placing them in different positions with respect to each other. But the reader, interested in this sort of detail, which is now purely historical, may gratify his curiosity by referring to the 'Transactions of the Society of Arts.' Macdonald's 'Treatise on Telegraph Communication' (1817), also contains a multitude of similar details.

Marine telegraphic communication is an object of great importance, since there are many circumstances which render personal communication between vessels at sea impracticable, and that sometimes in cases of the greatest emergency. But, although naval signals have been, of necessity, long used, and flags of various forms and colours have been extensively employed for the purpose of making them, it was not till within a comparatively recent period that they were reduced to anything like an efficient telegraphic system. Sir John Barrow states ('Ency. Brit.,' art. 'Navy') that "The idea of *numbering* the flags, and of assigning a certain number of corresponding sentences to certain combinations of these numbers, was reduced to something approaching a regular system in the fleet of Lord Howe;" and that in the year 1798 a new signal-book was issued by the Admiralty, the references to which were made by a numerical arrangement of flags. This book contained about four hundred sentences, expressive of the most usual operations of the fleet; but it was so imperfect that, if any order had to be transmitted which was not to be found in the dictionary, it became necessary to make the signal for "a boat from each ship;" an order which could not always be complied with. This inconvenience was remedied by the plan, suggested by Sir Home Popham, of making the flag-signals represent the letters of the alphabet, as well as words and sentences, in connection with numbers. He also printed, at Calcutta, a new code of naval signals, which was subsequently reprinted in England, greatly extended, and adopted for use in the navy. Among the numerous improvements introduced by him is a new method of cutting the signal flags, so that, as he explained to the Society of Arts in 1816, "the selvages of the buntin are brought on the outer edges of the flags, and the gorings in the centre; by which means the outer edge is susceptible of the least air of wind, and when the flag blows out, the gorings assist in keeping it out; whereas the old flags had a hem on the outside, which rendered them difficult to be moved without a fresh breeze, especially in damp and rainy weather, as the hem then became very heavy." "Besides," he adds, "it is impossible, from the nature of the buntin, to sew a straight seam, for the instant it is cut it will become in some degree curved." ('Transactions,' vol. xxxiv.)

The principle of the numerical system as applied to flag-telegraphs in the navy is briefly explained by Macdonald. Nine different variegated flags are employed to express the numerals 1 to 9, another for 0, and another called a *substitute*, to repeat any flag under which it is hoisted, in the case of the same numeral occurring twice in the number to be expressed. A pendant is also used in some cases as a substitute for the uppermost figure; and thus, by the use of eleven different flags and a pendant, any number from 1 to 999 may be expressed without displaying more than three flags, or two flags and a pendant, at once.

The Codes best known in England are those of the Admiralty, 1808, and again in 1816 and 1826, and the modifications which form the present Admiralty Code; Lynn's Code, 1818; Squire's, 1820; Raper's, 1828; Phillippe's, 1836; Rohde's, 1836; Walker's, 1841; Eardley Wilmot's, 1851; Roger's (American), 1854; Reynold's (French) 1855; Marryatt's (last edit.), 1856; Board of Trade (2nd edit.), 1859. In all these the general principle is the same as above explained. A certain number of flags and pendants of different patterns have to each its own name, some being expressed by numerals, others by letters, while a third set are used for specific purposes: one called the Interrogatory, asks a question; another signifies an affirmation, another a negation, and so on. In the Admiralty, this system is carried to a considerable extent, and requires about fifty flags or pendants; while there is a general system-book, by which orders are given for evolutions in the fleet, and much routine information. There is also a second telegraphic book, including common words in English, a list of ships in the Royal Navy, with the names of the flags by which each is distinguished, and other useful information. There is also a system of night signals, the same as the general signal book, but instead of flags, lamps, with or without blue lights or guns, convey the signals. There is also a system of fog-signals made by the firing of guns, the variations being marked by the intervals between the reports. In addition to all this, each commander is furnished with private and secret signals, which are only used to ascertain whether a ship of war is a foreigner or not; for if a foreigner the proper return signal will not be known.

A general code adapted to merchant vessels was invented by Captain Marryatt, and continued in use up to the year 1857, when the Board of Trade published their 'Commercial Code of Signals for all Nations,' which soon came into general use. It includes only 18 flags or pendants, which were named after the consonants, and were so arranged as to show the distinguishing flag of every British merchant ship, a list of such ships as are registered being published every year by the Board of Trade, with an official number to each. Each ship always retains its name and number, although it may change its port. The signals provided for were 20,000, and 4 flags the greatest number for any signal. The system was modified by a committee appointed by the Board of Trade in 1855, and as now in operation provides by means of 18 flags and 8 pendants for upwards of 70,000 signals: the flags and pendants are given under Flag. The signals are arranged in classes for easy reference. We may lastly refer to a system of boat-signals arranged by Captain Wilmot.

Sir John Barrow, in the article before alluded to, observes that a telegraph employed for public purposes should be possessed of *power*, *certainty*, *simplicity*, *celerity*, and *secrecy*. It should have sufficient power to express, by distinct positions or combinations of moveable parts, any possible order or information, either by letters, words, or sentences. Its certainty will depend upon all its parts being clearly defined, wholly within the field of the telescope, and so distinct that there shall be no risk of mistaking one signal for another; whence the importance of simplicity becomes obvious. In order to decide the question as to distinctness, the shutter-telegraph at Nunhead, near New Cross, was left standing for some time on the same hill as the semaphore; and the result of the trial for a whole winter was, "that the semaphore was frequently distinctly visible when the boarded telegraph was so much enveloped in mist and fog that the particular boards shut or thrown open could not be distinguished;" and that the number of days in the course of the winter upon which the semaphore was visible exceeded those upon which the shutters could be seen by fully one-third.

Any means of telegraphic communication which depends upon the deciphering of signals exhibited at a distant station is necessarily dependent upon contingencies of weather; but many plans have been contrived for effecting the object in such a manner as to be independent both of light and of the state of the atmosphere. For communication between the different parts of a house this object may be effected by a mechanical connection, by chains or wires, between two dials with revolving indexes or pointers, in such a way that when one pointer is directed to a particular letter or word inscribed upon the dial to which it is attached, the other may exhibit a similar movement. The attention of the servant is engaged previously by ringing a bell; and when the required signal has been made, a spring returns both indexes to their original position. Speaking-pipes, or tubes to convey the voice from one place to another, are also available for short distances, but their range is too limited for application on an extended scale. One of the early schemes of this character depends upon the principle of water finding its level; but, independently of the difficulty which might arise from the friction of water in a very long pipe of small diameter, such as would be required to connect the vertical tubes in which the observations would be made, such a plan involves the necessity of having all the communicating stations at or near the same level. Other hydraulic telegraphs depend upon the comparative incompressibility of water or other liquids; it being proposed to lay down small pipes of any required length, and to indicate different signals by pressing more or less upon the surface of the fluid contained in them, which would transmit the motion to the opposite end of the pipe, where it might be pointed out upon a dial, or in any other convenient manner. Mr. Vallance described such a method of telegraphic communication in a pamphlet, published in 1825, of which Hebert gives some account ('Engineer's and Mechanic's Encyclopædia'); and some similar schemes have been more recently propounded. Air confined in small pipes has also been tried to a limited extent as a pneumatic telegraph; but in this, as well as in the hydraulic system, the risk of leakage is a serious disadvantage.

TELEGRAPH, ELECTRIC. The attempts to render one or other of the phenomena of electricity subservient to the purposes of telegraphy, have been numerous. From the earliest date which we can assign to the existence of an electric telegraph, its essential parts have been the same. These are, 1st, the source of electrical power; 2nd, the conducting material by which this power is enabled to travel to the required locality; and 3rd, the apparatus by which at the distant end of the line, the existence of this power, its amount, or the direction of its action, is made known to the observer. In the earlier stages of the invention, the investigations of its promoters were confined to the last of these three essentials; and so long as the illustration of the idea was confined to the lecture-table, this part claimed pre-eminence. But, with the proposed application of the principle to purposes of general utility, there arose the necessity for an equal degree of attention to the two former requisites.

The experiments of Dr. Watson in England, in 1747, and of Franklin, in 1748, on the banks of the Schuylkill river, may have suggested the conveyance of information by means of electricity. The earliest authenticated instance of any attempt to reduce this idea to practice, appears to have been that of M. Lesage at Geneva, in 1774, and of Lomond in France, in 1787. They employed as an indicator a pair of pith balls, suspended from one end of an insulated wire, at the other end of which was the operator, provided with an electrical machine. On charging the wire with electricity, the pith balls would exercise mutual repulsion, and diverge from one another; but on removing the electrical charge from the wire by the contact of some conductor, the balls would collapse. It is evident that certain numbers of successive divergences might be made to denote particular preconcerted signals. Subsequently to this, the phenomenon of the spark, as seen on the passage of electricity through an uninterrupted conductor, was used for the transmission of signals. Were the various letters of the alphabet formed in this manner, upon a table, and connected each one with a distinct and insulated wire, any particular letter might be rendered visible in a darkened room, by passing an electrical charge through the appropriate wire. This in fact constituted the telegraph of Reusser, or Reiser, invented in 1794. Betancourt and Dr. Salva in Spain, in 1798, appear to have made experiments on the transmission of the charge through wires of great length.

A somewhat similar form of apparatus, involving the same principle, was constructed by arranging the several wires in succession, with a single break in each. The various wires bore the names of the different letters or figures, and any required signal was indicated by passing the charge through the proper wire, when the spark visible at the interruption of the circuit would denote the letter to the observer at the farther end.

This was the point to which the invention had advanced, at the commencement of the present century. The discovery by Volta, in 1800, of the pile which bears his name, forms the commencement of a new era in electric telegraphs, although there was no immediate application of the phenomena of the galvanic current to the purpose. Indeed several important discoveries had to be made before an electric telegraph of any value was possible.

In 1807, Sömmering at Munich proposed to construct an electric telegraph on the principle of the decomposition of water by the Voltaic current, as discovered in 1800 by Nicholson and Carlisle. The form of his apparatus was the following:—In a glass trough containing water, thirty-five gold pegs or pins were arranged vertically, this number of pegs corresponding to the letters of the alphabet, together with the nine digits. Each of these pins was connected with a wire, which extended to the place whence the signal was to be transmitted. At this point they terminated in brass strips, arranged in a frame side by side, but, like the wires and pins, insulated from each other. Each brass strip bore the name of the letter or figure which belonged to the pin to which it was connected. The operator, when wishing to send any communication, connected the two poles of the battery with the brass strips bearing the names of the two first letters required. Decomposition of the water in the trough at the distant end was instantly indicated by the evolution of bubbles of gas from the two gold pins, which thus became the two electrodes or poles of the battery. The letters forming any communication were to be in this manner denoted in pairs, the inventor ingeniously availing himself of the different quantities of the two gases evolved to point out the relative position of the letters in each pair, the hydrogen being employed to indicate the first letter. Schweigger proposed to add to this system a plan for calling the attention of the correspondent at the distant station by the discharge, by the current, of a pistol charged with the mixed gases.

In 1816, Mr. Ronalds, of Hammersmith, invented an electric telegraph, in which the use of frictional electricity was recurred to. This telegraph, which was shown to several scientific men at the date above given, was fully described by the inventor in a work published by him in 1823. Mr. Ronalds employed the divergence and collapse of a pair of pith-balls as the telegraphic indication, in which respect the principle was the same as that adopted by Mr. Lomond; but to this simple apparatus, a distinct contrivance was appended, in order to render the communication more rapid and easy. A single wire, perfectly insulated by being suspended from silken strings, or buried in glass tubes, surrounded by pitch, and protected by wooden troughs, was extended between the two stations. From the end of this wire was suspended in front of the dial of a clock a pair of pith-balls, so that while the wire was charged the balls would remain divergent, but would instantly collapse, when the wire by contact with the earth, or with the hand of the operator, was discharged. A person at one end having therefore an electrical machine by which he could maintain the wire in an electrified state, and the pith-balls at the farther extremity consequently in a state of divergence,—had it of course in his power to give an instantaneous indication to an observer at that farther extremity by touching the wire with his hand, which, discharging the electricity, would allow the balls to collapse for an instant. But instead of merely employing the successive movements of the pith-balls to denote the various signals, Mr. Ronalds added another apparatus for this purpose. Two clocks, very accurately adjusted to the same rate of going, carried, instead of the ordinary seconds hand, light discs, on which the various letters of the alphabet, the figures, and other required signals were engraved. These discs turned with a regular step by step movement, behind a screen of metal, in which was made a small opening, sufficient to allow of one letter at a time being seen. As the discs turned round, each letter in succession would be visible through this space; and it is evident that if the clocks were started with the same signal visible, the movement of the discs would bring similar signals into view at the same time. One of these instruments was situated at each end of the communicating wire. The operator who was about to transmit any communication, watched the dial of his clock until the letter he required was visible, and at that instant discharged the wire. The momentary collapse of the balls at the distant end would then warn the observer to note the letter visible on his instrument, which would form a part of the intelligence to be received. The successive letters or signals constituting any message were denoted in this manner as the clock dials continued to turn round. In order to avoid the necessity for constant attention on the part of the observer, an arrangement was adopted by which a pistol could be fired by the spark at the farther end, to summon the attendant to his instrument. Various signals were also concerted beforehand, by the use of which the time necessary for the transmission of any intelligence was lessened. These experiments of Mr. Ronalds' were made with the intervention of several miles of wire, carried backward and forward across his grounds.

In 1819, Professor Oersted of Copenhagen made his great discovery of the action of the galvanic current upon a magnetic needle. He observed that when a current is passed along a wire, placed parallel and near to a magnetic needle, free to turn on its centre, the needle is deflected to one side or the other, according to the direction in which the current is transmitted. He further noticed that the position of the wire, whether above or below the needle, had an equal influence with the direction of the current in determining the side to which the deflection took place. [ELECTRO-DYNAMICS.] The power of a single wire in causing this deviation of a needle is but small, but this was remedied by the invention of the *multiplier*, or GALVANOMETER, by Professor Schweigger, in which the needle, being surrounded with many successive coils of insulated wire, is acted upon by the joint force of all. Under a somewhat different form, this discovery now forms the basis of the needle electric telegraph.

Very shortly after this important discovery had been made, Arago and Ampère in France, and Seebeck in Berlin, succeeded in rendering iron magnetic, by the passage of a galvanic current through a wire coiled around the iron, and Sturgeon in England produced the first electro-magnet. [ELECTRO-MAGNETISM.] It was found that, provided the iron to be magnetised were perfectly soft and pure, the magnetic property remained only during the actual transmission of the electricity, and was lost immediately on the interruption of the electric circuit. If the iron which was exposed to the influence of the galvanic current were combined with sulphur, carbon, or phosphorus, the magnetic power became to a greater or less extent permanent in it.

The invention of the voltaic battery, of the deflection of the needle, and of the magnetisation of soft iron, formed the three great steps in the history of the electric telegraph.

M. Ampère suggested the employment of the discovery of Oersted as early as 1830, and this suggestion was acted upon by Professor Ritchie, in a model telegraph exhibited by him at the Royal Institution. Ampère's plan however was far from possessing the simplicity so essential in an instrument designed for practical use. Not less than thirty pairs of conducting wires were necessary, according to his scheme, for maintaining a telegraphic communication.

Baron Schilling also, in Prussia, in 1832 and 1833, following the idea originated by Ampère, proposed a similar form of telegraph, in which there were as many of these galvanometers, each with its appropriate circuit, as there were letters or signs to be used in the various communications. In fact there were 36 needles and 72 wires. In 1833, Gauss and Weber proposed to employ the separate movements of a suspended bar as signals: but its indications must have been feeble, as they had to be observed through a telescope placed at some distance from the oscillating bar. In 1837, M. Alexander exhibited a model of a proposed form of telegraph, containing 25 needles, to be acted upon as in Ampère's arrangement. In this instrument a distinct needle was employed for the indication of each letter, these needles bearing at one end light screens of paper, which concealed from view a letter or figure, until by the deflection of the needle the screen was removed, and the letter brought into sight. M. Alexander, however, effected one great improvement, in substituting a single return wire, to which one end of all the coils was joined for the several distinct return wires existing in the previous invention of M. Schilling. At a later period this gentleman undertook a series of experiments, with a view to the establishment of a communication by means of a single wire; but some mechanical difficulties appear to have arrested his progress. In both of these telegraphs all that was requisite, in addition to the indicating apparatus and conducting wires, was a contrivance by which the connection of the voltaic batteries could be made with any pair of wires in the former, and with any single wire and the return-conductor in the latter of the two inventions. In M. Alexander's instrument, a set of keys resembling those of a pianoforte, and corresponding to the number of needles, was arranged on a frame or table. One pole of the battery being connected to the return or common wire, the other pole was joined to a plate of metal, or to a trough of mercury, extending beneath all the keys. On depressing any key, the wire belonging to it, which was continued to the end over the battery connection, was brought into contact with this bar or trough. The current would then flow along the conducting wire, around the multiplier-coil in the distant instrument, and return by the common wire to the voltaic battery. The keys bore the same letters as the needles to which they were connected, so that the operator communicated any letter by pressing down the corresponding key.

In these two instruments no use was made of the power which exists of determining the deflection of the needle to either side, by merely reversing the connections of the battery.

We have thus traced the history of the telegraph up to the point at which it first assumed the practical form in Cooke and Wheatstone's inventions; but what had been accomplished remained either unknown or was known only to a few leading men of science, until the unexpected development of the electric telegraph in the hands of those gentlemen led each one who was in possession of any title to the merit of having believed in, and experimented upon, its possibility, to produce his title, or to have it eagerly put forward by his friends and fellow-countrymen.

Fig. 1.

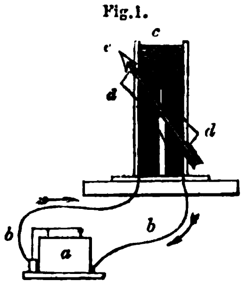


Fig. 2.

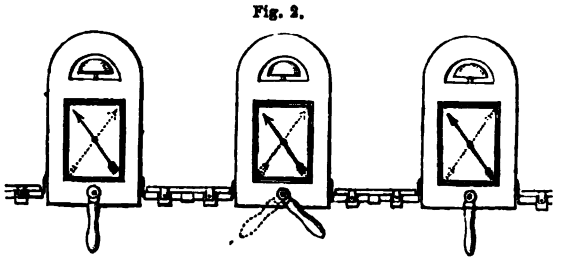
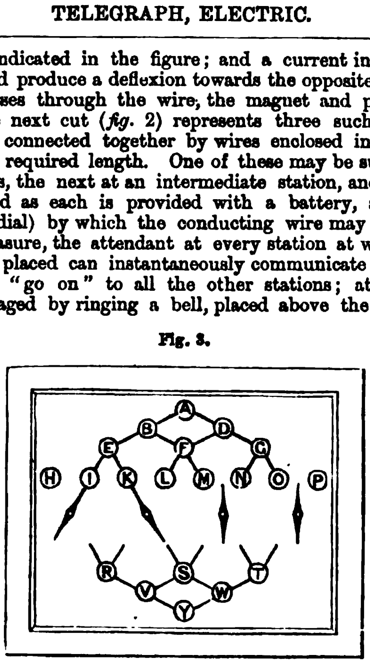


Fig. 3.

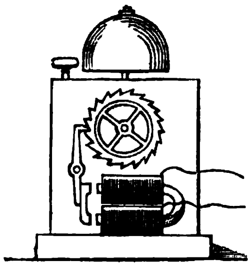


In June, 1837, the experiments of Messrs. Cooke and Wheatstone, which had been progressing for more than a twelvemonth, appeared so far successful as to induce them to apply for a patent for their inventions. The principal points of novelty in this patent were the use of a much smaller number of needles to denote all the required signals, the employment of the temporary magnetism excited by the current in soft iron, to ring an alarum; and the reciprocal arrangement by which the invention was rendered practically applicable to a long line of communication. In explaining the invention, Mr. Cooke ('Telegraphic Railways') says:—"If a magnetic needle were placed parallel and near to any part of a conducting wire, which we will suppose to be laid down between London and Blackwall, the transmission of an electric current from a voltaic battery would cause the needle to change its position, so as to stand during the continuance of the current at right angles to the wire, being turned in one direction or the other according to the course of the current. If this deflexion of the needle were limited by two fixed stops placed respectively at the two sides of one of its poles, the motion of that pole to one stop might evidently constitute one signal, and its motion to the other stop another signal." Such an apparatus is shown in *fig.* 1, the dial upon which the signals are represented being removed. In this cut *a* may be supposed to represent the battery, and *b b* the conducting wire, which is formed behind the dial into a coil *c*: *d d* is the front or index needle, mounted upon an axis passing through the coil, another needle on the same axis being within the coil. The front needle carries upon its extremity, which comes through the dial, an index or pointer *c*. The arrows indicate the direction of the current required to deflect the magnet to the position indicated in the figure; and a current in the opposite direction would produce a deflexion towards the opposite side. While no current passes through the wire, the magnet and pointer remain vertical. The next cut (*fig.* 2) represents three such instruments complete, and connected together by wires enclosed in tubes, which may be of any required length. One of these may be supposed to be at the Minories, the next at an intermediate station, and the third at Blackwall; and as each is provided with a battery, and a handle (beneath the dial) by which the conducting wire may be connected with it at pleasure, the attendant at every station at which such an instrument is placed can instantaneously communicate the signal to "stop" or to "go on" to all the other stations; attention being previously engaged by ringing a bell, placed above the dial. *Fig.* 3 represents a dial, in which, by the combination of four such magnets and pointers, all the letters of the alphabet may be expressed by pointing one or two needles towards them; and of course a larger or smaller number of signals might be made on the same principle if necessary. A telegraph with two pointers, showing eight signals, is considered by Mr. Cooke to be sufficient for all ordinary purposes. The wires, where several are used, are covered with some insulating material (such as a mixture of cotton and caoutchouc), and combined into a rope and enclosed in an iron tube, which may be either buried beneath the surface of the earth or supported above it.

The instrument which was brought into use on the Great Western Railway shortly after the date of the patent, contained five needles, arranged with their axes in a horizontal line. The needles when at rest hung vertically, by reason of a slight preponderance given to their lower ends. Each coil was connected with one of the long conducting wires at one end, and was united at the other with a rod of metal, which joined together the similar ends of all the coils. The current was transmitted from the opposite end of the wires (where a set of five pairs of finger-keys, for making the connections with the battery, was placed) through two of the wires at once. That is to say, one of the wires, of which one key was pressed down, served to convey the current from one pole of the battery to the distant instrument, while the key of a second wire being brought into contact with the other pole, the current returned by the rod of metal connecting the coils and the second wire to the battery again. Two needles were in this manner deflected at once, and it will be obvious that the current would pass in opposite directions around their coils, and consequently that the deflections must be in contrary directions. The needles would therefore converge, either above or below their line of centres, as one or other of the pair of keys belonging to each wire was depressed. Fixed stops were so placed on each side of the needles as to limit their motion, and when resting against them, the needles were parallel to two converging lines, at the point of intersection of which a letter was placed. (*Fig.* 3.) This was the signal indicated by the movement of the needles. In a similar manner, as lines were drawn diverging from the centre of each axis, mutually crossing one another, a number of points of intersection were formed, at each of which was a letter or signal. Any of these letters could be indicated by the simultaneous movement of two needles, so that a communication could be carried on with certainty and tolerable rapidity. At the same time a plan was recognised, by which the number of wires requisite for maintaining a communication might be reduced, by using one of them at times as a return wire only, there being no needle in connection with this one. One needle could by the use of this wire be deflected by itself either to the right or left, and thus of course each would furnish two signals, in addition to those formed by its simultaneous deflection with any other. The instruments at the two stations were always rendered reciprocating; that is, at each end of the line were placed an instrument, a set of finger-keys, and a voltaic battery, so that either station could transmit or receive a signal. By an ingenious arrangement, the keys, on being released after depression, were made to resume by themselves the position necessary to enable that which had been the signalling station to become the recipient. By this means messages and answers, or words and their acknowledgments, could follow one another without the necessity for any intervening adjustment of the instruments.

The bell or alarum which was to be rung, when the attention of the clerk at the distant terminus was required, was either direct or indirect in its action. In the first case the attraction exercised by a horse-shoe piece of soft iron, rendered temporarily magnetic by the galvanic current, was made to draw an armature, likewise of soft iron, towards it, and by this action impel a small hammer against a bell. In the second form of alarum, *fig.* 4, the movement of the armature merely released a detent or catch from a train of clock-work driven by a spring or weight. This clock-work, by the intervention of a scape-wheel and pallets, rang the bell as in a common alarum.

Fig. 4.



In April, 1838, Mr. Cooke obtained a patent for some further improvements in this apparatus. Of these the most prominent was the mode of introduction of the intermediate apparatus. Before the date of these patents, the two stations at the extremities of a line of telegraph had alone been put in communication with each other; but means were now devised by which any number of intermediate instruments might be introduced between the two terminals, and any intelligence rendered simultaneously visible in all or in any of them, as required. Furthermore any one of these instruments could be put in communication with the rest, either generally or in part only; and the same mechanical adjustment which limited the connection of any intermediate instrument to one part of the line, placed its bell in the circuit of the other part. Thus if, while intelligence was being transmitted in one direction from an intermediate station, some message of importance were required to be sent from the terminus, or any other station on the excluded side, the ringing of the bell at the communicating station would warn the attendant to restore his instrument to its intermediate position, and thus leave the line clear throughout.

In the same patent were included some improvements on the mode of protecting and insulating the wires, which were to be laid beneath the earth, in tubes or troughs of wood, iron, earthenware, or other material; and also in the expedients for detecting the exact position of any accident or derangement, without the necessity of uncovering the whole length. Two needles were also shown to be sufficient for carrying on a complete communication with ease and rapidity.

In the course of the ensuing year (1839) Messrs. Cooke and Wheatstone's telegraph was brought into actual operation upon the Great Western Railway, where its capabilities were tested. The results of this trial demonstrated that the undertaking was thus far successful, and that the question of the practicability of the electric telegraph, so long at issue among scientific men, was set at rest.

We must here go back a little, to notice Dr. Steinheil's telegraph, which was erected between Munich and Bogenhausen in 1837. In this instrument, two needles or magnetic bars were placed within an elongated coil of fine wire. These bars were suspended on axes passing transversely across the coil, and in their quiescent position lay parallel to one another and to the sides of the coil. They had their poles placed the same way, so that when a current was transmitted along the wire, they had a tendency to move in the same direction, remaining still parallel to each other. Against the outer end of each needle or bar a stop was placed, which checked its motion on one side, but left it free to turn to the other. The opposite poles of the two bars were therefore prevented from moving out from the coil, under the influence of the deflecting current; and the effect of this arrangement was, that the two bars could not move simultaneously, but only alternately. Both were acted upon alike, but when the inner end of one was free to move outward, the other bar remained pressed against its stop, and was fixed; and on reversing the current, the effects upon the two needles were also reversed; that which was before stationary, now moved forward, while the other was fixed. In order to bring back the needles to their ordinary position, a permanent magnet was fixed near to each at the back of the coil, by the attraction of which the needles were again rendered parallel after the cessation of the deflecting power of the current. The inner ends of these bars carried each a light brass arm, terminating in a cup furnished with a small perforated beak or spout. These cups were filled with printing-ink, which oozed through the beak, and formed a minute bead or drop at its point, which, from its viscid consistence, did not drop off. These beaks were arranged so as to be in the same horizontal line, and at a distance from each other a little less than the width of a strip of paper, which was placed before them. If then a galvanic current were passed through the coil, so that the right-hand needle tended to pass, with the end bearing the cup, out from the coil towards the paper (the cup on the other needle receding as far as the stop would allow, and then remaining fixed), the little beak would just touch the paper, and leave a minute dot of ink on its surface. By reversing the current the other needle would approach and leave a point of ink on the opposite edge of the strip of paper. By the varied number and arrangement of these dots, on one or both edges of the paper, the various letters of any communication were denoted. The paper used in this apparatus, being obtained in a long strip or ribbon, and coiled upon a roller, was made to pass slowly lengthwise before the printing points by a simple application of a weight and cord, which as the printing was effected gradually wound the ribbon upon a second drum or reel. This instrument was also adapted to give audible signals, by the substitution of small knobs for the ink-cups, and of two bells of different tones for the ribbon of paper. One bell being so placed as to be sounded by the first needle, and the other by the second, the pre-concerted combinations of their sounds might indicate various letters to a listener.

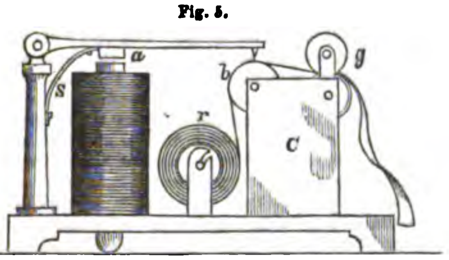
In the construction of his telegraph, Dr. Steinheil made a capital discovery. He found that the conducting power of the earth might be made to occupy the place of the return wire. All that is necessary is, that the wire which connects the two ends of the metallic conductor with the earth, shall be carried to a sufficient depth below the surface so as to be always in contact with moist earth or with water: and that it shall be at this point attached to a plate or other piece of metal, of about two or three feet superficial. For the ordinary Voltaic battery, Dr. Steinheil substituted the magneto-electric machine; in which, according to Faraday's great discovery, the electric current was derived by induction from a permanent magnet.

The electric telegraph invented by Prof. Morse, of America, has led to a large amount of controversy, a claim having been put in for him as the first actual inventor of a practical electric telegraph in 1832, while on board the packet-boat Sully. The Abbé Moigno states that a Mr. Jackson wrote to the Académie Française, affirming that he had, in 1832, communicated this plan to Mr. Morse, while returning together from Europe to America, on board the Sully. Even admitting, however, the claims of either party, it would only show that they did not think sufficiently well of their scheme to enter upon it until nearly three months after the first English patent for an electric telegraph had been sealed, and the practicability of such an apparatus demonstrated in England. The first really official letter on the subject from Professor Morse, is dated September 27, 1837. Cooke and Wheatstone's first patent for an electric telegraph was sealed three months before this, namely, on June 12, 1837. The difference between this telegraph and the preceding suggestions and contrivances was very great. The experiments of these gentlemen had been proceeding for a long time previously, so that when in June, 1837, their patent was obtained, it was not for an arrangement of doubtful practicability, or of a form to be perfected only after repeated trial. On the contrary it was, within a few months after the date of the patent, put up and brought into actual and daily use. Some of its details have since been simplified, and the modes in which the electric current is made to give the required indications have been greatly varied; but the great features and principles of their first invention remain unchanged, and not only so, but they form an essential part of nearly if not quite all the later telegraphs of other inventors.

The telegraph exhibited by Morse in September, 1837, was essentially a registering instrument, the various signals being traced on a strip of paper. The plan appears to have been the following:—an electro-magnet was so placed as to be within attracting distance of an armature fixed to the shorter arm of a lever, of which the longer end carried a pencil projecting sideways from it, and pressed lightly against a sheet of paper. This paper, by a contrivance analogous to that of Dr. Steinheil, was made to travel slowly beneath the pencil. So long as no attractive power was exerted by the electro-magnet, the pencil would continue to trace a straight line as the paper moved onwards; but on momentarily making the circuit with the battery, the armature was drawn to the electro-magnet, and the pencil, carried by the arm of the lever upwards, made an angular mark, like the letter V reversed, on the paper. These angles might either be joined in groups, by rapidly succeeding completions of the circuit, or they might be separated by longer or shorter spaces of straight line. The nine digits were represented by corresponding numbers of angles, and these were combined so as to form all possible numbers. A short space intervening between two or more successive groups, denoted that they must be taken together to form a total of two or more places of digits; while a longer space showed the actual completion of one number and the commencement of the next. All the necessary words were represented by various numbers, as arbitrary signs, a previously arranged dictionary being used for their interpretation. This plan had also been proposed by Mr. Ronalds, to simplify the working of his telegraph.

In the telegraph erected by Professor Morse, in 1844, between Baltimore and Washington, a different mode of recording the signals was adopted. The use of the pencil was found objectionable, from its so frequently requiring fresh pointing, and from the risk of breakage. The same arrangements were retained in regard to the paper, but it was made in its course to pass over a roller having a groove around it. The long arm of the lever carried a blunt steel point, standing over the groove in the roller. When therefore the arm of the lever was depressed, by the attraction of the magnet upon the armature, the steel point pressed the paper into the groove, and produced an indentation. If the attraction were momentary, a depressed point was produced; but if the action were continued for a longer time, a lengthened depression was the result, as the paper was drawn on. The combinations of these two kinds of marks denoted the various letters and figures. Thus, dot and dash . — is taken to signify *a*; — . . . to signify *b*; — . — . for *c*; — . . *d*; . for *e*; and so on. This is called the dot and dash code. *Fig.* 5 shows the arrangement of what is called the *symbol-printing* telegraph: *a* is the armature attached to the lever which carries the steel point. The ribbon of paper is drawn slowly off from its roller *r*, by a train of clockwork in the box c, which drives two gripping rollers *g*. In its passage the paper goes over a brass roller *b*, containing the groove. If while the paper is thus being drawn over the roller *b*, the clerk at the communicating station were by means of a common telegraph key or handle to transmit the current for an instant, the armature would be momentarily drawn down, and the steel point would mark the paper with a depressed dot. The spring *s* would raise the arm the moment the magnet had ceased to act. But if, instead of transmitting only a momentary current the communicating clerk were to continue the transmission for a short time, the arm would be pulled down during that time, and the point would indent a line in the paper.

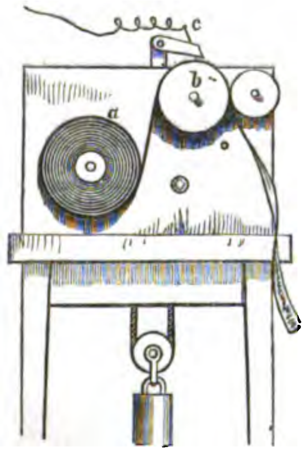
Fig. 5.



In July, 1838, Mr. Edward Davy obtained a patent for improvements in apparatus for making telegraphic signals by means of electric currents. The principal feature in this patent is a *chemically marking* telegraph, in which a local circuit (completed by galvanometer needles acted on by the line circuit, and forming the basis of what is called the *relay system*) marks chemically prepared paper, which is moved forward by clockwork released by an electric magnet. Two line wires are used to convey the electric current and one return wire, with a battery and two galvanometers (deflecting opposite ways) to each wire; the battery to the return wire giving a preponderance to currents through that wire, twelve different signals can thus be produced. The action is as follows: on one or more of six keys being pressed down, either two or three of the galvanometers act; and as the three wires admit of the current proceeding in either direction through them, it can complete either two or three out of the six circuits of the local battery; thus marking longitudinally properly prepared paper at two or three out of six places. The clock-work escapement for moving the paper a sufficient distance between the signals, consists of two levers, one of which carries the armature, and works on a horizontal axis carried by the other lever. When the armature is attracted, it releases a pin from a notched fly vane, and enables it to move half a revolution; and when the current ceases, the pin is again removed, and replaced by lateral motion given to the second lever by a wheel pressing against a projection on it. Calico "impregnated with hydriodate of potash and muriate of lime," is preferably used to receive the marks or signals.

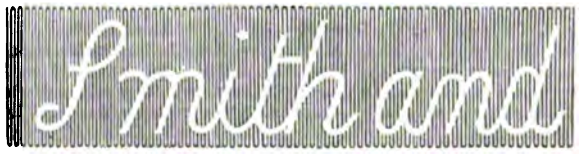
We may here state in more precise terms the principle of the *chemical printing* telegraph. A train of clockwork is used to keep a ribbon of paper constantly unwinding from a drum, and passing over a metal roller *b*, *fig.* 6. A small steel wire *c*, connected with the wire from the line, presses lightly on the paper on this metal roller, so that any current sent through the wire shall, in its way to the earth, pass through the steel wire *c*, through the paper strip, to the roller *b*. This paper being chemically prepared with a colourless solution, is coloured when decomposed by the passage of an electric current through it. In this way, by regulating the duration of the current, the paper can be stained in dots and lines, as in the symbol-printing arrangement.

Fig. 6.



An ingenious modification of the chemical printing telegraph was made in the *writing telegraph*. It is evident that if, instead of employing a long ribbon of paper, enough of it were taken to pass once round the roller *b*, and if this roller not only rotated on its axis, but was also by means of a screw made to advance slowly from side to side as it rotated, the steel wire would trace on the paper a spiral line. If also, instead of communicating by a key, there were at the other end another roller, exactly like *b*, and which by means of clockwork could be turned at precisely the same speed as *b*, and with the same rate of shift endwise, then a tracer, resting on this second roller would, if the current were kept continually passing, trace precisely the same spiral as the wire on the first roller *b*. But supposing the current only to be maintained by the pressure of this tracer against the metal roller, and if the surface of the roller were partly covered with a non-conducting material, such as shell-lac or resin, the tracer in passing over this as the roller turned round, would cease to make its stained mark, but it would begin to mark again as soon as the tracer had come upon the metal. In using this machine the words of the message are written on a slip of tin-foil in a non-conducting varnish. As soon as this is dry, the tin-foil is wrapped round the tracer roller, and the tracer being made to bear upon it, the two rollers, one at the communicating and the other at the receiving station, are started at the same moment. Then, while the tracer rests on the tin-foil, the wire on the roller *b* will continue to make its stained spiral line on the prepared paper; but whenever in its passage the tracer rests on a piece of the varnished writing, the current will be broken, and the spirals traced by the steel wire will be interrupted; which interruptions will evidently coincide with the writing which has passed under the tracer; so that on taking the paper off the roller, there will be a fac-simile of the original writing in clear spaces left free from the parallel lines traced close together over every other part of the paper. This fac-simile will appear like *fig.* 7.

Fig. 7.



In January, 1840, and in July, 1841, Professor Wheatstone obtained two important patents, the first of which was in connection with Mr. Cooke. The *electro-magnetic* telegraph may be regarded as a variation of the alarum; but instead of the detent, there are two light spring pieces, shown in *fig.* 8, one with a hook-shaped end, and the other an obtuse wedge or pushing piece (known as a *clawker and driver*), and instead of the catch-wheel of the alarum, there is a light escapement wheel. Under this arrangement each movement of the armature towards the magnet will pull the wheel round one tooth, and the motion of the armature from the magnet by means of a light spring, will push the wheel round another tooth. The axis of the wheel carries a light index hand, which points as the wheel turns round to the various letters arranged near the edge of a disc. The currents which work this telegraph are sent by means of a *communicator*, *fig.* 9, consisting of a brass disc turning freely on its centre, and marked with letters, as in the disc, *fig.* 8. Opposite each alternate letter, the brass is cut away, and a small notch of ivory inserted, so that on turning round the disc a metal spring, which bears against its edge, rests alternately on the conducting brass and the non-

Fig. 8.

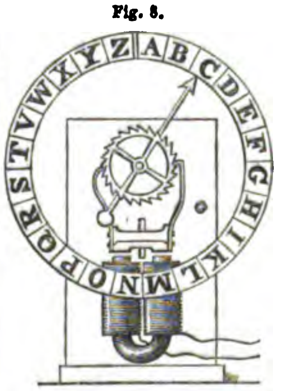
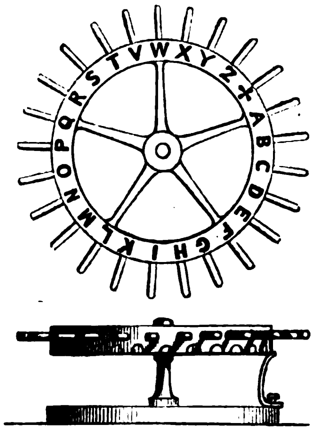


Fig. 9.



conducting ivory, whereby the current is alternately transmitted and interrupted. A radiating arm proceeds from each letter for the convenience of turning the disc. If the disc stand so that its stop-mark + be opposite to a fixed mark, the spring is resting on an ivory piece, and if at the same moment the index of the distant telegraph in connection with it be also pointing to the +, then on moving the communicator one step forward, so that the letter A comes to the fixed mark, the current will be transmitted along the wire, the electro-magnet, *fig.* 8, will draw down its armature so as to pull the wheel one tooth forward, and make its index also point to the letter A. On again moving the communicator so that the index points to B, the current is interrupted, the armature of the distant telegraph falls back, pushing the wheel round another tooth, and bringing its index also to B. In this way the index may be moved step by step to different letters so as to spell out a word or message, which word or message will be repeated on the disc of the distant telegraph. A slight pause is made after each letter of the message, to insure certainty; numerous modifications have been made in this machine, for increasing the rapidity of its action. An addition of printing mechanism to this instrument forms the *type-printing* telegraph. In this the escapement axis, instead of carrying a fixed disc, has light radiating arms of steel, at the ends of which are printing-types *a*, *figs.* 10, 11. In front of the types is a small roller or plate *b*, for receiving the blow of a printing-hammer *c*, which stands behind the type disc. The paper which receives the impression is placed between the roller and the type disc, which paper is coiled on the roller *d*, and is drawn off by passing between two other rollers *e*, which hold the paper tightly and turn a little way round after each blow of the hammer.

Fig. 10.

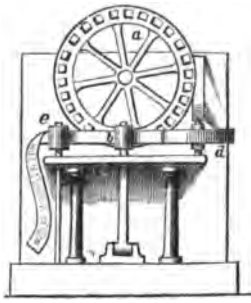
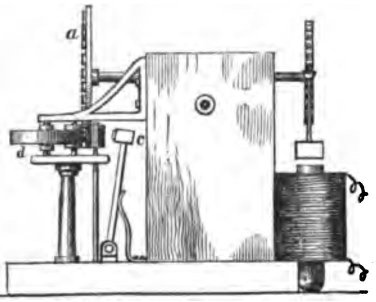


Fig. 11.



The action is as follows:—The type-disc is turned round by alternately transmitting and interrupting the current until the proper letter is brought into the proper position to be struck, when, the hammer being released, it presses the type on the paper. The drawing-rollers immediately jerk the papers forward through a space equal to that of one letter, when the type-disc is again moved onward to the next letter required, which is struck in like manner, and so with all the rest of the letters in the message. The hammer usually strikes by the force of a spring, which is released by the train which acts upon the drawing-rollers. The mechanism is so contrived that the hammer cannot strike while the type-disc is in motion, but falls as soon as a pause is made, that is, when the right letter is brought into position. The types are inked by means of a small roller smeared with printing-ink, which, as the type-disc revolves, presses lightly against their surfaces. Or a ribbon of carbonic ink transfer-paper may be drawn round between the type-disc and the white paper ribbon. Numerous variations have been made in the type-printing telegraph, the best known of which is by Mr. Bain. In this machine the types were arranged on the edge of the disc or wheel, radiating from its centre; and the printing of any one upon the cylinder was effected by the movement forward of the entire type-wheel and its axis, by a crank and connecting gear in the printing train, instead of one punch or type only being struck down by the printing-hammer, in impressing a signal. It was also proposed to use two clocks at the two communicating stations, to rotate the type-wheels with a uniform motion. These clocks, having been adjusted to exactly the same rate, and being started from the same signal, would bring continually, at each station, similar type opposite to the paper-cylinders at the same moment. The action of this part of the apparatus is exactly analogous to that of Mr. Ronalds', already described. A hand or index revolving on a dial in front of the machine, at the same rate as the type-wheel, indicates to the operator the signals which are successively in a position ready for printing in his own instrument, and therefore, if the clocks go accurately together, in a similar position in his correspondent's instrument. At the same time this hand, by coming in contact in its revolution with a pin, placed by the operator opposite to any signal that he wishes to print, completes the electric circuit at this moment, and by so doing stops the type-wheel, and releases the printing-train at each station. A similar figure having thus been impressed on the cylinder at the two ends of the line, the operator removes the pin, and replaces it opposite the next signal he requires to send. The moment the pin is removed, and the circuit therefore broken, the hands and type-wheels at each station resume their evolutions which are again checked by the contact of the hand and pin as before. It should be stated that the idea of the two clocks, as well as that of the printing-telegraph, was borrowed from Wheatstone.

Bain's *single-index* telegraph, which was the instrument proposed by him for practical use, consisted of two hollow cylindrical coils of wire, placed horizontally a short distance apart, with their axes in the same line. Between them a small bar-magnet was fixed across a delicate spring, which in front passed through the dial-plate of the instrument, and was turned up to form an index. The two coils were connected, so that an electric current entering from the line wire would pass through both. When this was the case, the bar-magnet would be attracted towards one coil, while at the same time it would be repelled by the other. These actions tended to carry the magnet to the same side, as far as the spring to which it was attached and a fixed stop would allow of its moving. The reversal of the current inverted the effects of the coils, and the magnet would then pass to the other side. The combinations of these two movements represented the various letters and signals, they being denoted to the observer by the index on the dial of the instrument. The movement of the index to the left denoting the letter I, and to the right the letter V, this instrument obtained the name of 'I and V Telegraph.'

In 1842, Mr. Bain patented his proposed plan for working an electric telegraph by means of an *earth battery*. At one end of the line he buried in moist earth a large plate of zinc, and at the other end a plate of copper, iron, or other substance such as coke or charcoal, which might act the part of a negative plate to the zinc. Then, on connecting these distant plates with a wire insulated from the earth, a current of electricity would constantly pass from the one plate to the other. Indeed, the distant plates connected with the wire, as above described, may be regarded merely as a battery of one pair of plates, separated by a very wide interval of exciting material, represented by the earth. It was at first supposed by Mr. Bain that this current would be applicable to all telegraphic purposes, but subsequent experiments showed that it was available only for a few miles of distance; its intensity not being sufficient to enable it to travel through any great length of wire. In some cases, where a constant current of low intensity is required, this earth battery might be of use.

In 1843, Mr. Cooke introduced the mode of extending the wires between distant places, so that their insulation from one another, and from the earth, might be maintained without the expense and difficulty hitherto incurred; before this period the wires having been covered with cotton, and insulated by coating them with shell-lac, resin, or pitch, had been laid down in pipes of wood or iron. It was now proposed to insulate the wires by suspending them in the air upon posts or standards of wood or iron, the wires not coming in actual contact with any part of the standard, but passing through rings of porcelain or earthenware. [Glass was afterwards found to be the best insulator.] The standards were usually fixed at from forty to sixty yards asunder, and at each quarter of a mile a stouter post was placed, to bear the winding or straining apparatus. This was a simple winding-reel, connected with a ratchet-wheel and click to prevent its recoil, after the wire had been strained up by its means. The intermediate posts within each quarter of a mile only supported the wire, without reference to its tension, which depended solely on the winding posts. Instead of the copper wires hitherto employed, iron wires of a larger size were now used. By the adoption of this method of extending the conducting wires, the cost of construction of an electric telegraph was reduced nearly one-half, and at the same time the risk of imperfect insulation was diminished. So long as the wires were buried in tubes beneath the ground, it was always deemed prudent to add a return wire, extending from one end of the line to the other; as it was found very difficult to render the insulation sufficiently good to enable the earth itself to be used as half of the circuit. The tendency of the electric fluid to escape from the wires in the tubes to the earth, was much greater than to another wire lying in the same tube, so that the latter plan was always adopted. But when the suspended conductors came into operation, the insulation was rendered so complete, that the earth was subsequently in all cases used to return the current, by which means an economy of one wire throughout the whole line was effected. In addition to this, another advantage was gained by the suspension of the wires, in the facility with which accidental errors or injuries were discovered and rectified. While the tubes were in use, it was necessary to supply, at about each quarter of a mile along the line, a proving or testing post, within which the wires were brought up to a box, so as to afford the means of examining any of them as to their insulation and conducting power. For this purpose, Mr. Cooke had invented an instrument called the *detector*, by which the perfect state of each wire could be tested, and the position of any error or fault discovered with considerable accuracy. Still, with all these appliances, the detection and repair of any derangement of the wires demanded considerable skill, and led to no small expense. But when the wires were in sight throughout, any contact or fracture was at once visible, and was easily and quickly repaired.

We must here pause in the attempt to trace the history of this great invention through the medium of its patents. The reader who is desirous of pursuing the subject in this way, is referred to one of the valuable volumes printed by order of the Commissioners of Patents, entitled 'Abridgments of Specifications relating to Electricity and Magnetism, their Generation and Applications' (1859). This volume contains an introduction of xciii. pages, and an abstract of patents extending to 728 pages, exclusive of a copious index. A single specimen of this index will show the extent of patent influence that has been exerted down to the year 1857. For example: under 'Telegraphs' (Electric), we have for acoustic telegraphs, 14 patents; copying telegraphs, 8; dial telegraphs, 68; embossing, 1; gold leaf, 2; magneto-electric, 23; marking, 33; needle, 39; pointer, 32; portable, 7; printing, 44; and recording telegraphs, 5 patents; while the component parts of electric telegraphs are the subjects of separate patents under distinct heads, such as alarums, telegraphic, 76 patents; insulators, 42 patents; galvanic batteries, nearly three columns of names.

It is not, however, too much to say, that amidst this formidable list of patentees in our own country, without referring to claimants in Europe and America, there are but a very few names—perhaps only one name—that posterity will care to remember in connection with the practical working of the electric telegraph. Although the principal facts necessary to the construction of an electric telegraph had been known, as we have seen, ever since 1821, yet it was not until the general establishment of railways that telegraphic wires could be safely carried to any great distance. Moreover, the importance of the invention was by no means understood. The government was satisfied with the working of the semaphore; railway directors looked upon the electric telegraph as a new-fangled invention, and the public was not yet alive to its innumerable advantages. One fact, however, must be insisted on, namely, that to this country belongs the honour of this great invention; that in the year 1837 a needle telegraph had been invented, so complete, and at the same time so simple in its operation, that it could be worked by any one who knew how to read; that in June of that year the patent for this telegraph had been sealed, and, a month later, the wires were laid down between the Euston Square and Camden Town Stations of the North-Western Railway, a distance of a mile and a quarter, and that on the 25th of July messages were actually sent between these two stations, Professor Wheatstone being in the Euston Square Station, and Mr. Cooke in that at Camden Town, the witnesses being the engineers, Messrs. Fox and Stephenson. Now, it is quite true that M. Arago claimed, before the French Academy of Sciences, for M. Steinheil the precedence in this matter, inasmuch as he had his telegraph in operation on the 19th of July, 1837; but it must be remembered that Wheatstone's patent was taken out in the June of that year, and was based on numerous previous successful experiments; whereas Steinheil published no description of his instrument until August, 1838, and it is admitted that in the interval he had altered and amended his instrument, and soon afterwards abandoned it for a modification of one by Morse. The claim of the last-named gentleman we have already disposed of. In September, 1837, he exhibited an imperfect instrument, although he afterwards succeeded in producing one of first-rate excellence, which is still largely used in the United States of North America.

But to return to Cooke and Wheatstone's telegraph: it received notice to quit the London and Birmingham line, but Mr. Brunel gave the patentees permission in 1839 to lay it down on the Great Western Railway. This was first done as far as West Drayton (13 miles), and it was afterwards extended to Slough (18 miles), the wires in both these preliminary trials being inclosed in iron tubes laid on the ground. On proposing to extend this line to Bristol, much opposition was offered by the directors, and the telegraph again had notice to quit. But on the proposal of Mr. Cooke to retain the line of wires at his own expense, he was permitted to do so, on condition of transmitting the railway signals free of charge, and of extending the line to Slough. In return for this favour, he was allowed to transmit messages for the public, which was accordingly done, one shilling being charged for a message; but the public did not avail themselves much of the new instrument, and its value was scarcely appreciated until the 3rd of January, 1845, when it was used to convey a message to the London police, directing them to arrest Tawell on a charge of murder, the message flashing past the criminal while he was travelling express to escape the consequences of his crime. By the end of 1845 upwards of 500 miles of telegraph were in operation in this country. In 1846 the Electric Telegraph Company commenced their operations with a considerable capital, a large portion of which was expended in the purchase of Wheatstone and Cooke's patents, and the system which they had introduced became rapidly extended. In due time other telegraph companies were competing with the original company, the system spread over Europe, and soon no railway was deemed complete without its telegraphic wires. In the United States of America the telegraphic system is far more complete and extensive than in the Old World; but the telegraph wires are for the most part independent of the railways, and hence, it is said, arises the larger number of railway accidents in that country. But the telegraphic system could not be regarded as complete while nations separated from each other by seas and oceans remained unconnected by the electric wire. So long back as 1840, Mr. Wheatstone stated to a parliamentary committee his conviction of the practicability of uniting Dover to Calais by means of a telegraphic wire, and two years later he had made arrangements for a line across Portsmouth Harbour, although circumstances over which he had no control prevented its being carried out. About this time the introduction of gutta percha offered itself as an excellent insulating material for the wire, and its first application was made in 1847, by Lieut. Siemens, of the Prussian artillery, for a line across the Rhine at Cologne. The first submarine wire was laid down in August, 1850, by the "Submarine Telegraph Company," between Dover and Cape Grisnez, near Calais. It was a copper wire inclosed in gutta percha. About 27 miles of it were conveyed on board the Goliath steam-tug, and wound round a large iron drum to facilitate the paying out. The end of the wire attached to the land was conveyed to the South-Eastern Railway Terminus, and the vessel started from Dover, paying out the wire, and attaching pieces of lead to it at intervals to assist it in sinking. Electric communication was kept up hourly. At length the vessel came to an anchor off Cape Grisnez, and the end of the wire was sent ashore in a boat. Several messages were passed between the two shores during the day; but on attempting to resume the correspondence next morning, no answer could be obtained. It was ascertained that the wire had snapped asunder; but the experiment proved the possibility of connecting England with the Continent by means of a submarine electric cable. In the following year a stronger cable was laid successfully, and has continued to work down to the present time, notwithstanding occasional injuries from the anchors of ships and boats. In 1851 and 1853 lines were laid between England and Ireland and England and Belgium. In 1853 a line was laid from Orfordness to Schevening in Holland; in fact four separate cables were laid, each containing one conducting wire, so that the injury to one line might not interfere with the working of the others. In the same year a line was laid across the Solent, from Hurst Castle to Yarmouth, in the Isle of Wight. The first line of considerable length, however, was that laid in 1855 between Balaklava and Varna, during the Crimean war. This line was 310 miles in length, and consisted of a copper wire covered with gutta percha, except at the shore ends, which were protected by iron wire. This line was laid by Messrs. Newall, and it remained in good order for some months, until the end of the war, when it was broken. This temporary success of the Black Sea Telegraph led to the formation of the Atlantic Telegraph Company. The attempt made by this company to lay a line to America in 1857 failed from the breaking of the cable after about 335 miles had been payed out. Another attempt in 1858 was apparently successful, and messages were exchanged during three weeks between Valencia, in Ireland, and Newfoundland; but the signals became variable and feeble, and at length ceased altogether. And thus was lost 3000 miles of cable, and 375,000*l.* sterling, for the value of the cable can scarcely exceed the expense of lifting it, and therefore its recovery will not probably be attempted. It is now proposed to alter the route for this line, and to carry a cable by way of Greenland to America. In 1854 the Mediterranean Telegraph Company laid down wires between Spezzia and Corsica, and between Bonifacio and Sardinia, and from thence in 1855 to Algeria. This last cable seems to have failed. In 1857 the British government agreed to assist the company in the construction of a line from Cagliari to Malta, and thence to Corfu. This line has been unfortunate. Another line from Portland to the Channel Islands has met with several accidents, and the experience with it, as well as with the Red Sea and India telegraph cable, show the wisdom of the Report made by the Board of Trade, that our knowledge in 1859 was not such as to justify the submerging of another deep sea cable, without further experiments being made; and they recommended the appointment of a committee to investigate the subject. A committee was accordingly appointed, and from the connection with it of such men as Professor Wheatstone, Mr. E. L. Clarke, and Mr. Varley, we should hope for a great increase of our knowledge on the subject. While we are writing, a case is under investigation which shows the necessity for this inquiry. A cable manufactured for the government for the purpose of connecting Falmouth with Gibraltar, had its destination changed in the spring of 1860 to a projected line from Rangoon to Singapore. In order to preserve the cable, it was placed in water-tanks, but when transferred on board the ship which was to convey it to India, it was coiled dry, and the moisture imbibed by the hemp, being gradually squeezed out, caused the iron covering to rust; and as this process of rusting generates heat enough to soften the gutta percha, the safety of the cable became endangered, so that it had to be again taken out of the ship and deposited in tanks.

The practical working of a telegraph involves such a multiplicity of details, that we cannot attempt in an article of this kind to convey much minute information. Still, however, there are certain prominent features which a reader moderately acquainted with electrical science will readily understand. An electric telegraph, whether for land or sea, consists of three essential parts: 1st, the *transmitting apparatus*, for generating electric action at one end, known as the *sender;* 2ndly, an electrode or insulated path along which the electricity may travel, and familiarly known as the *line* or the *wire*, or, in the submarine telegraph, the *cable;* 3rdly, the apparatus used at the other end of the line to render evident the signals forwarded by the transmitting apparatus: this is called the *receiving apparatus* or *instrument*, or simply the *instrument*.

And first as to the transmitting apparatus. This is usually a voltaic battery, consisting of alternate pairs of copper and amalgamated zinc plates, arranged in troughs of some compact wood made tight with marine glue, subdivided into compartments by means of slate, or the troughs are of glazed gutta percha. Each compartment contains the copper of one pair and the zinc of the next. [GALVANIC BATTERY.]

After the plates have been introduced, the compartments are filled with sand, which is moistened with dilute sulphuric acid (1 strong acid to 15 water). This arrangement diminishes the risk of leakage, and lessens the amount of evaporation. The acid has to be renewed once in ten or fourteen days, according to the amount of work performed by the telegraph. In the Electric Telegraph Company's central office at Lothbury the batteries are contained in two long narrow chambers in the basement of the building. There are upwards of sixty Daniell's batteries at work: they take rank as sixes, twelves, and twenty-fours, according to the number of their elements or plates, the twenty-fours working the longer lines, and the smaller batteries the shorter circuits. A twenty-four, when in full work, requires only a gill of dilute sulphuric acid per month, and its zinc plates last three months. Other batteries require 1 lb. of sulphate of copper per month, with a little sulphate of zinc or salt and water. The entire amount of electric power employed by this company throughout the country is said, on the authority of an article in the 'Quarterly Review' (1854), to be produced by 8000 twelve-plate batteries, or 96,000 cells, which are lined with 1,500,000 square inches of copper, and about the same of zinc. To work these batteries, 6 tons of acid and 55 tons of sand are required every year. When a distant station-clerk finds by the weak action of his needles that the battery is not up to its work, he sends word that it requires "refreshment," and it is accordingly served with its gill of sulphuric acid.

Another form of battery which continues in action for a considerable time consists of plates of amalgamated zinc and gas coke excited by solid sulphate of mercury moistened with water; they are arranged in compartments as in the sand battery.

Some lines are worked by means of the magneto-electric machine. [MAGNETO-ELECTRICITY.] The Atlantic cable during a portion of its brief existence was worked by a secondary current. An electric cable sunk in water is apt to become charged with electricity after the manner of a Leyden jar, and so to resist the passage of the current along its central conducting wire. The idea was, that by using a secondary current it would by its pulsations displace the charge, and allow the current to be transmitted. Mr. Whitehouse fed his double induction coils by means of what he calls a "perpetual maintenance battery." This battery consists of large plates of platinized silver, and amalgamated zinc, mounted in cells of gutta percha. There are several plates, both of silver and zinc, in each cell; but all the zinc plates rest upon a longitudinal bar of metal at the bottom of the cell, and all the silver plates hang upon a similar bar at the top of the cell, so that thus there is virtually but a single stretch of silver, and a single stretch of zinc in operation. This arrangement is made because it enables any portion of either silver or zinc to be removed for repair or renewal without stopping for a moment the operation of the battery. As any one lamina becomes imperfect, it can be taken out from its groove, and replaced. Each cell contains two thousand square inches of acting surface, and is charged with the usual mixture of acid and water, and there are ten such cells in the battery. This combination is so powerful that when the broad strips of copper plate which form the polar extensions are brought into contact or separated, brilliant flashes are produced, accompanied by a loud crackling sound. The points of large pliers are made red-hot in five seconds when placed between them, and iron screws burn with vivid scintillation. These brilliant effects are, however, produced at the expense of the apparatus; the metallic surfaces from which they are emitted rapidly burning away during their continuance. In order to alleviate this injurious effect, contact is made and broken, during the transmission of electrical signals, by means of a key presenting a very large surface of metal. A horizontal bar, flattened at the top, turns backwards and forwards pivot-ways, and tilts its edges against twenty flat brass springs resembling in form the keys of a piano-forte, ten being on each side. A constant slight leak of the current is also continuously maintained through a coil of platinum wire placed in water. By this contrivance the injurious force of the spark is pretty well absorbed and destroyed. The cost of maintaining this magnificent battery at work is said not to exceed a shilling per hour.

But for the reason above stated the voltaic current is by no means a fleet messenger compared with other agents which are at the command of the electrician. Consequently it is not the electric stream generated in this powerful battery which was designed to be actually sent across the Atlantic on the performance of telegraph service. This primary power is only used to call up and stimulate the energy of a more speedy traveller. The voltaic current, generated in the battery, is transmitted to induction coils, arranged in pairs, each coil being arranged as in Ruhmkorff's apparatus, a figure of which is given under MAGNETO-ELECTRICITY, col. 428. It is the secondary current induced by this apparatus which it was proposed should perform the work of rushing across the Atlantic. This independent secondary current was therefore the *transmission current*, and the coil in which it was produced was properly the *transmission coil*. The coils were used in pairs, because each one inductively increases the power of its neighbour, and in return has its own energy inductively increased as well. The great heating power of the battery-current is rendered harmless by the size and extent of the primary coil through which it is passed. If at any time, by accident, the current should find a short course for itself in consequence of the silk covering of the wire being injured, the accident is immediately indicated by the rapid rise of the temperature of the coil. The transmission-current necessarily gets considerably weakened when it has passed through a distance of 1800 or 1900 miles. Consequently this weakened current was not to be immediately employed to print or record the signals transmitted. The weakened transmission-current was merely caused to open and close the outlet of a fresh battery destined to do the printing or recording labour. The strand of the Atlantic cable was continued into a coil of fine wire, wound about a bar of soft iron. When the transmission-current flowed through the coil, the bar became a temporary magnet, which had the direction of its polarity determined by the nature of the current (positive or negative) sent through the coil. The pole which is north when the transmission-current is positive, becomes south when the transmission-current is negative. Near to the temporary magnet a permanent magnet was so placed that it could traverse backwards and forwards upon a pivot as it was actuated by the temporary magnet. The north pole of the permanent magnet was attracted by the south pole of the temporary one, and *vice versâ*; so that as the polarity of the temporary magnet was reversed, the permanent magnet was made to traverse. When it traversed one way, it opened the outlet of the local battery by effecting a contact, and caused it to print; when it traversed the other way it shut off the current of the local battery, so that it ceased to print.

It was the peculiar advantage of this relay-instrument (as it is called) that the temporary magnet had no other work to do than to turn the permanent magnet upon its almost frictionless pivot. It had no spring to overcome, such as is more commonly employed in this class of instruments. The arrangement was so sensitive that the apparatus could be put in action by a fragment of zinc and a sixpence pressed against the tongue. These relays might indeed be ordinarily heard clicking backwards and forwards, and working automatically when the large induction-coils were in operation within a few feet of them, actually doing a little business on their own account, although not in communication with any current, and transmitting the same signals and messages as those which were being forwarded through the agency of the induction-coils. As the poles of the induction-coil magnets were reversed, the poles of the relay-magnets were actuated different ways. Mr. Whitehouse made the instruments even more delicate by applying a second permanent magnet, so that it could be made by a screw-adjustment to increase or diminish the attraction acting on the working magnet, either way. When the printing battery was brought into operation by the relay, it delivered its message by the agency of one of Professor Morse's printing instruments already described.

Professor W. Thomson, in commenting on the above arrangement ('Encyc. Brit.,' art. 'Electric Telegraph'), prefers the voltaic battery to any other source of electricity "for all great telegraphic work;" and he expresses his conviction—somewhat boldly, we think,—that "if no induction coils and no battery power, either positive or exceeding 20 cells of Daniell's negative, had ever been applied to the cable since the landing of its ends, imperfect as it then was, it would be now in full work day and night, with no prospect or probability of failure."

Secondly, as to the *line*.—In most parts of England the wires, as from the commencement of the system in this country, are supported on poles at a height of several feet from the ground; but in a few cases, such as along the mail-coach road from London to Dover, a subterranean arrangement has been adopted: the wires being encased in a wooden trough, and deposited a foot or two beneath the surface of the ground. This arrangement is also adopted in the streets of London, and of other large towns. It has also been adopted by the English and Irish Magnetic Company, on a great extent of their lines; and it is that adopted in Prussia. The wires from the central station in London are insulated by being wrapped with cotton thread, and coated with a mixture of tar, resin, and grease, or gutta percha is used in preference. Nine such wires are packed in a half-inch leaden pipe, and four or five such pipes are packed in an iron pipe about 3 inches in diameter, which pipes are laid under the foot-pavements, and are thus conducted to the terminal stations of various railways. Testing-posts are placed at intervals along the streets, by which any failure can be detected and the locality of the defective wire ascertained at least within the distance of two posts. The London District Telegraph Company do not bury their wires, but are now engaged in weaving a metallic web over the tops of our houses.

The exposed conducting wires which run along the side of a railway are of galvanised iron, about the sixth of an inch in diameter. The higher price of copper prevents it from being employed, although this metal is a much better conductor of electricity than iron. When a great length of wire is to be stretched between two distant points, without immediate support, steel wire is sometimes used. The galvanised iron wire, in the neighbourhood of large manufacturing towns, is liable to be attacked by the sulphur acids of the smoke, and the zinc being converted into a soluble sulphate is washed off by the rain, and the iron wire becomes quickly corroded. We have already spoken of the earthenware or glass insulators attached to the posts, for supporting the wire. An insulator should not only be a non-conductor, but it should throw off the rain quickly and completely, otherwise the moisture will form a conductor to the earth; indeed, the dripping of wet from one line to another below it, will sometimes turn away the current from its work. Wet and foggy weather always has the effect of diminishing the current and requiring greater battery power; unless, indeed, the plan should be adopted of *switching* the line, that is, instead of sending a message along a direct line, where the wires are enveloped in rain or damp fog, or are otherwise "sick" as it is called, the line is switched on to another and more circuitous route, where the wires are in good working order. Spiders' threads covered with dew sometimes divert the current, as does also atmospheric electricity. Indeed, a thunder-storm was formerly a source of danger to the telegraph clerks. Professor Loomis says that the telegraphic wires are very sensitive to an approaching storm, and often become highly charged, even when the storm is so distant that the thunder cannot be heard nor the lightning seen. Under such circumstances, if one stand in the room of a telegraphic station, and place one hand upon a telegraphic wire, and rest the other on the wire which communicates with the earth, a sharp shock is felt in the arms, and sometimes across the breast. This shock is very painful; although when the two wires are brought within striking distance of each other, only a faint spark is to be seen. But when the thunder-cloud is near, such experiments are dangerous. In such case, a thunder-cloud passing over the wires may charge them to such an extent that the electricity may fuse the thin wire of the electro-magnet, and render the magnet itself unserviceable. On some occasions an explosion takes place in the telegraph-room sufficient to fuse thick wires, and to expose the clerks to considerable danger. A weak charge of atmospheric electricity has the same effect on the wires as the current of a voltaic battery; it makes a point in the telegraphic register. If, however, a storm pass over the wires, these points become numerous; and as they show themselves between the points of a telegraphic message, they make the writing indistinct, and often illegible, so that on such occasions the clerks usually suspend their labours. Various contrivances have been made for drawing off electricity from the wires, without disturbing the current, advantage being taken of the tension of the former, which gives it a striking distance not possessed by the latter. In addition to atmospheric electricity the line is liable to be disturbed by what are called "earth currents." If both ends of a long wire be connected with the earth, currents will pass through the line apparently in consequence of variations in the electrical condition of the earth in different places. Mr. Varley has observed that these currents are continually flowing about the earth in one direction or another throughout the day, and reach a maximum about 2·40 P.M. During magnetic storms or the aurora borealis, currents are sufficiently strong to interrupt the working of the lines: they flow sometimes in one direction, sometimes in another, and often change their direction in a few seconds.

But if in land lines the insulation of the wires is attended with difficulty, the insulation is very much more difficult and uncertain in carrying a cable through great lengths of ocean. In transmitting a current along an insulated land line connected with the earth at one end, and with a battery communicating with the earth at the other, the strength of the current diminishes in an inverse ratio to the length of the wire. When, however, the conducting wire is wrapped up in an insulating material and immersed in water, we have the three parts of a Leyden jar, namely, the wire takes the place of the inner metallic coating, the gutta percha that of the insulating glass, and the iron wire covering or the water that of the outer coating, so that not only does the strength of the current diminish inversely as the length, but the arrangement must be discharged before a message can be sent, and the rate of signalling must depend ultimately on the rapidity with which the charge and discharge can be effected.

But there are mechanical difficulties arising from the materials employed. The copper conducting wire is deficient in strength, and a moderate strain put upon it may produce a permanent elongation: while the materials which envelope it, being more elastic, return to their original bulk when the strain is removed, the elongated copper does not do so, but will thus cut its way through the gutta percha cover. The copper wire is usually made into a strand for the sake of strength, and it has even been proposed to cover the copper with fine steel wires before putting on the gutta percha, so that the chief strength of the cable might be in its core. Copper wire is preferred on account of its superior conducting power for electricity, which is seven times greater than that of iron. But this superiority is greatly dependent on the purity of the copper. No substance added to copper increases its conducting power; but the presence of other metals may reduce its conducting power below that of iron. The conducting power of copper also varies with the temperature.

Gutta percha is also subject to various changes which interfere with its insulating power; although usually considered as a good insulator it is by no means perfect, especially when it is exposed to a tolerably high temperature. At 32° there is a very small leakage of electricity through it; at 52° the leakage is three times as great; at 72° it is nearly six times; and at 92° ten times as great as at 32°. While laying the Red Sea cable, the temperature in the hold of the ship was 92°, and the insulation was so bad that the engineers could not speak through the cable; but when in the water at the depth of 300 fathoms and the temperature 73°, the insulation became much better. Gutta percha also varies greatly in its quality: it may contain foreign matter, or be porous, or air bubbles may become entangled with it during the laying on, all of which may tend to destroy its insulating power. There may be bad joints or small punctures, or a strong battery power may produce a chemical action injurious to its stability. Its durability is also seriously affected by exposure to light and air, so that in shallow water india rubber may be a preferable coating. Gutta percha is also liable to injury from friction or from pressure, and both it and the hempen packing are liable to the attacks of marine animals, a species of Teredo devouring the hemp, and another Teredo penetrating the gutta percha.

Hence it will be seen that the great problem of ocean telegraphy cannot by any means be regarded as solved. The best form of cable remains to be invented: it should be light and flexible for deep waters, and sufficiently strong in shallow ones to resist the rude grip of an anchor. Some cables weigh 3 or 4 tons per mile; others 8 or 9 or even more, while light cables weight about 1¼ or 2 tons per mile. The method of stowing them on board a ship, and the machinery for paying them out require to be reconsidered; but, above all, the many costly blunders which have been perpetrated with various cables ought not to be again possible, such as the heating of the Rangoon cable, and the error in reckoning in paying out the Cagliari and Algeria cable, so that there was not enough cable to reach the land: the ship held on during five days to the cable and then broke off in the midst of a storm. It is not our business here to do more than allude to the failures of telegraphic cables consequent on the plan adopted by our government of granting premiums to telegraphic companies.

This part of our subject will not be complete without a few details as to the mode of preparing the Atlantic cable. A strand of seven wires of pure copper of the No. 22 gauge, was first prepared, it being the sixteenth of an inch in diameter when twisted. The strand of seven wires was adopted in preference to a single wire of the same practical capacity, because the probability of a destruction of continuity was in this way greatly diminished. In case of any accident occurring it was very unlikely that all the seven wires would be broken in exactly the same place, and so long as only one of them remained sound, the electrical transmission could be carried on. The strand itself was subject to a strain which stretched it twenty per cent., without any appreciable injury to its conducting power being discovered. To show that no amount of attenuation which could be produced by accident, could interfere to any important extent with its utility as a telegraphic conductor, one mile of wire eleven times smaller than the strand, was introduced into a gap made in a 600-miles length of the cable, and the effect produced on the transmitting power of the cable by the interpolation was tested. It proved that the transmitting capacity of the cable was only diminished by one thirty-seventh part.

As the copper strand was prepared, it was rolled upon drums, and then taken from the drums to have three separate coatings of gutta percha applied, until the aggregate diameter was thus brought up to about three-eighths of an inch. The gutta percha used for these coatings was prepared with great care. It was first rasped into shreds, and washed, and next pressed through several layers of fine wire gauze, and kneaded for hours in the interior of iron cylinders by steam machinery. It was then squeezed by powerful screws, through dies, as the strand of copper was gradually drawn along between them, and so made to adapt itself as a compact sheath to the strand. Three several and successive coatings were given to the strand in order that any imperfection left in the first might be compensated and remedied by the next coat applied. The completed core was subjected to a pressure of five tons upon the square inch, by the use of hydraulic power, without the insulating material being at all injured by the force applied.

During the process of the manufacture of this core it was submitted to constant examination to prove both that the continuity of the copper strand continued unimpaired, and also that the insulating power of the gutta percha sheath was as complete as it was required to be. The continuity was proved by passing a voltaic current of *low intensity* from a battery of a single pair of plates, through the strand, and then causing it to record a signal after issuing from the wire. A battery of low intensity was employed for this purpose, because it made the test so much the more severe. A strong battery might have thrown the current through a slight imperfection, which a weak battery might not be able to overcome. The due perfection of the insulation was tried by turning up into the air the end of the length of core about to be examined, and by then connecting one pole of a voltaic battery of five hundred pairs of plates with the nearer end of the length of wire, and the other pole with the earth, a magnetic galvanometer being suspended within a coil continuous with the strand. So long as the insulation of the strand was fairly perfect, the copper wires became charged with the electricity of which but very little could escape, and so no current was produced through the strand, and no deflection of any consequence appeared in the magnetic needle. When the insulating sheath, on the other hand, was imperfect, the electrical charge *leaked* through the imperfections to the earth, and so got back to the opposite pole of the battery. In this way a current was set up in the wire to supply the leakage, and the magnetic needle was deflected from its position of equilibrium, the deflection being in proportion to the amount of the current. A strong battery of five hundred pairs of plates was employed in detecting imperfect insulation, in preference to a weak one, because a strong current would force a passage through an imperfection which might be too slight to allow a weak current to make its way. During the progress of the work, a plan was devised which enabled the testing for both continuity of the strand and insulation of the sheath to be carried on simultaneously. A voltaic current can pass through a charged Leyden jar without either the current or the charge being in any practical way interfered with. Therefore the entire length of cable under examination was joined up into a loop or endless ring, and a voltaic battery of five hundred pairs of plates had one of its poles connected with the conducting strand of this ring, and the other pole placed in communication with the earth. A small *insulated* battery of low tension was also introduced into the circuit of the ring, so that its current flowed round continually, from pole to pole, through the strand. An insulated bell was also so placed in the circuit, that any break of continuity dropped a needle, before held magnetically fast, and caused the bell to sound. Another bell instrument was so arranged that it was rung whenever the current from the five hundred-cell battery began to run, in consequence of electrical leakage, with undesirable speed. The feeble battery in the circuit rung its bell whenever the circuit was broken. The strong battery out of the circuit rung its bell whenever an outflowing current was set up through the strand, in consequence of the insulating sheath being unable to retain the charge.

During the prosecution of these experiments the discovery was made, that the insulating power of gutta percha is very materially affected by temperature. A high temperature seems greatly to impair its insulating capacity, and the recurrence of a low temperature speedily restores it to its original excellence. An opportunity was taken, when a single flake or tier of the completed cable was lying at the bottom of the receptacle in the yard of the manufactory at Greenwich, to watch the changes which the natural variation of temperature during forty-eight hours produced in its conducting capability. When the thermometer stood at 42°, the deflection of the galvanometer needle was barely 3°; but when the thermometer rose to 59°, the deflection of the magnetic needle became 64°. Even passing sunshine and cloud made the telltale needle traverse out and in with surprising rapidity. There was reason to conclude, from the soundings taken by Lieutenant Dayman of the Cyclops, that the bottom of the Atlantic would supply the low temperature essential to the good performance of the insulating material.

The separate lengths of manufactured core were joined into longer extents in the following manner. The gutta percha was scraped from the ends for a short distance, and these were placed in contact. A piece of copper wire was then attached by firm brazing to one side of the joint, and *wound* round the strand until it reached as far on the other side, being there brazed again. A second binding was then effected outside the first in precisely the same way, and several layers of gutta percha placed over the whole by the aid of hot irons. In case of the core on each side of the joint being at any time so dragged that the ends of the strand were broken asunder, this outer investment of wire would unroll spirally without being detached from the strand. Thus the electric continuity of the strand would be preserved even when the strand itself was severed.

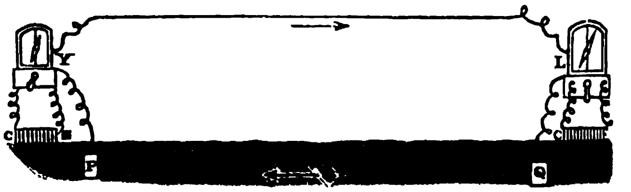
Every two miles of the completed core were wound upon channelled drums with deep flanges, iron shod at the rim, so that they could be rolled about and made to perform their own locomotion. When the contents of these drums were used in supplying the cable with more core, one of the ends was attached to the outgoing core of the compressed cable, and so the contents were unrolled from the drum as the external metallic wires were spun round the core. During the unrolling, a serving of hemp, saturated with a mixture of pitch and tar, was compactly wound round the core to act as a bed for the external metallic sheath. Then eighteen strands, each of seven wires of charcoal iron, were twisted firmly round the core. The strands and the cable were made by precisely analogous machinery. A large horizontal table, containing seven bobbins on the circumference in the case of the strand machine, and eighteen in the case of the closing or finishing machine, was whirled round by steam-power with great rapidity. A central wire, or the core, was drawn up through a hole in the middle of the table, and so invested with a twisted whorl of wires or strands, given off from the bobbins as the table revolved. The strands were used in completing the cable, instead of solid wires, because by this means greater flexibility and strength, for the material used, were obtained. The external investment of iron was solely designed to protect the coated core from mechanical violence during the act of submergence, and to confer upon it a convenient amount of weight for effecting its sinking in the sea.

Each strand-machine, during the manufacture of the cable, was worked day and night, and in twenty-four hours spun ninety-eight miles of wire into fourteen miles of strand. The several strand-machines at work simultaneously every twenty-four hours transformed 2058 miles of wire into 294 miles of strand. As much as thirty miles of cable have been made within twenty-four hours. At one time all the wire-drawers in England proved to be unable to supply the exacting demands of the machinery, and the works had to pause for a short space. The entire length of wire, iron and copper, spun into this wonderful structure, amounted to 332,500 miles; a length sufficient to engirdle the earth thirteen times! The completed cable weighed from nineteen hundredweight to one ton per mile, and proved to be able to bear with impunity a direct strain of five tons. In the salt-water the weight of the cable would, however, not exceed fourteen hundredweight per mile; and as the greatest depth of the Atlantic in which it would have to be laid is only a little more than two miles, and a certain portion of the weight would necessarily be borne by friction against the particles of the water as the rope sank, it was anticipated that the cable would never, under any circumstances, be required to meet a strain of more than one ton and a half.

The failure of the Atlantic cable was due, in some respects, to the haste with which it was manufactured. The company had obtained, in 1854, the exclusive right, for fifty years, of landing cables on the shores of Newfoundland and Labrador, and in 1856 the British as well as the American government made a grant of 14,000*l.* a year, conditional on success, the company pledging themselves to make the first attempt to lay the cable in 1857. It is now admitted that the construction of the cable was hastily commenced, before the experiments necessary to ascertain the proper form and other conditions had been completed. "The manufacture was, however, not fairly commenced till February, 1857, and 2500 miles were completed in June, 1857. Half was made at Messrs. Newall's works at Birkenhead, and half at Messrs. Glass and Elliot's works at Greenwich. The manufacture was very much hurried. The portion made by Messrs. Glass and Elliot, not being under cover, suffered from exposure to heat. The testing of each coat of gutta percha in water was recommended by Mr. Whitehouse, but this could not be performed on account of the speed at which the cable was required to be made. In the manufacture of the last 400 miles a system of testing the copper wire for its conducting power was introduced, by which an improvement of from 20 to 25 per cent. in the conductivity of the cable was obtained. Messrs. Newall's half of the cable was put on board the United States' ship Niagara, and Messrs. Glass and Elliot's half wasput on board the Agamemnon; but so backward were the preparations, that the machinery for laying the cable was being put together as the ships went round to Valentia. The break machinery was novel and cumbrous." ('Edinburgh Review,' 1861.)

The object for which all these complicated arrangements are made is for the purpose of indicating at the distant station certain electric signals by visible motions or by sounds, or by marks on a ribbon of paper. In all these cases there must be a contrivance for connecting the voltaic battery or other electro-motor with the line, in such a way as to be able to send along it a positive or a negative current at will, so as to be able to produce variety in the signals at the distant station, and having performed its work there, the current returns back to the battery by way of the earth. In this way, as already explained, the circuit is completed without the necessity of a return wire. Although a line of earth, as a conductor of electricity, is many thousand times inferior in power to a line of metal of the same diameter, yet as the conducting power of bodies increases in proportion to the area of the section of the conductor, and the area of the conducting portion of the earth between the two stations may be indefinitely extended, we thus have a return line offering less resistance than the wire which conveys the current. All that is necessary, therefore, instead of the return wire, is to bury a large copper plate in the earth, and to connect with it a wire from the telegraphic apparatus at the end of the line. Instead of this copper plate, or *earth* as it is called, the gas-pipes and water-pipes of towns are used as earths. In the Electric Telegraph Company's Central Station at Lothbury, an earth was formed by digging a hole in the foundations until moist ground was arrived at, and into this a cylinder of copper, 40 lbs. in weight, was sunk, and this was covered up with crystals of sulphate of copper. All the earth-wires of the establishment are connected with this earth-plate. The general arrangement will be made clearer by means of *fig.* 12, in which Y and L represent two telegraphic instruments, one stationed in York, another in London, connected by an insulated air-line. P Q are two earth-plates, connected by means of wires to each instrument. A message, we will suppose, is being transmitted from London to York. If C Z represent the battery at the London Station, the current will pass from C, to a wire connected with the earth-plate Q, thence through 200 miles of earth; when at the York earth-plate, P, the current will be taken up again, and, by means of the wire, will act upon the instrument Y, from which it will pass to the line, return back to London, pass through the coil of the instrument, deflecting the needle, and so back to the end Z of the battery, where the current will be completed.

Fig. 12.



Now, in order that the clerk may have it in his power to send the current in either direction, so as to deflect the distant needle either to the right or to the left at pleasure, some such arrangement as the following is necessary. There are many arrangements, more or less simple, having the same object in view, but we give this one for the sake of illustrating the principle :—*Fig.* 13 represents the galvanometer coil, with its needle, *n s*, at rest, or in a position to *receive* a message. Now, suppose the current from the distant battery to enter the coil G by the wire L. It will pass through the coil and come out by the left-hand wire connected with a metallic spring, V. It will then pass along the brass cross-piece *d* to the metallic spring *t*, and complete the circuit by means of the wire attached to the earth-plate P, and the earth, by which it returns to the distant station. The battery C Z, at the receiving station, remains inactive, its extreme wires being attached to insulated pieces of brass at either end of the vertical piece connected with *d*. Hence no current can pass, since the wire from C is insulated. If, however, a signal has to be transmitted from this instrument to the distant station, the clerk works the handle in front of the instrument, and presses *d* against the spring *t*, *fig.* 14, whereby the lower extremity of the brass piece is brought into contact with the other spring, V, and the current now passes in the direction of the arrows, that is, from C to V, through the wire attached to P, into the earth through the distant station, where the instrument is arranged for receiving the signal, as in *fig.* 13, where it produces a deflection of the needle; the current then returns by L to the galvanometer coil G, deflects the needle, and returns by the wire attached to the spring *t*, and so by the metallic piece *d*, through the wire attached to Z, and thus completes the circuit. By reversing the motion of the handle, the direction of the current, and the motion of the needles in the coil, will be reversed, both in the near and in the distant instrument, as in *fig.* 15. When the clerk has finished making his signals, the springs V and *t* restore the cross-piece *d* to the position shown in *fig.* 13, so that the instrument adjusts itself for receiving signals from the distant station, the battery C Z is thrown out of action, and the conducting communication with the line is restored by means of the cross-piece *d*. In this way the same motion of the needle is produced at the same instant at both stations, so that the sender and the receiver of the message each perceives the signals.

Fig.13.

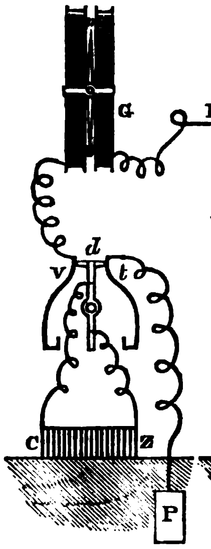


Fig.14.

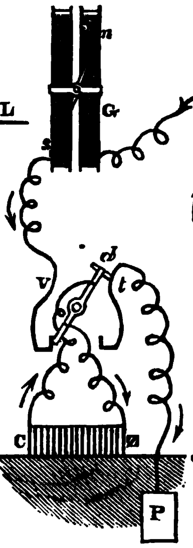
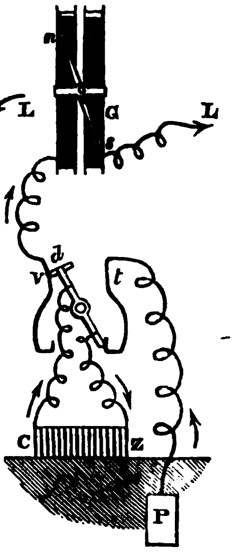


Fig. 15.



There is in general but one needle in connection with each galvanometer coil. The astatic arrangement formerly adopted is not now in use; the outside needle, by which the clerk knows how the signals are proceeding, being formed of ivory, or some inert substance, attached to the same axis which carries the magnetic needle within the coil. The needles are limited in their motions by means of small ivory studs fixed in the dial, and they are thus prevented from swinging too far over, while their motions are made precise and clear. It was formerly the practice to give a preparatory notice of a message to the distant station by ringing the electric alarum, but this was found to be so intolerable to the persons in waiting that it has been abandoned, and the clicking sound of the needle against the ivory studs is sufficient to draw the attention of the clerk to the arrival or passing of a message. When a message is sent from London to York, for example, all the needles of the intermediate stations are similarly deflected; but each clerk knows, by a special signal, when he is required to be spoken with. There are, however, contrivances called "commutators," by which a message is made to pass any one or more stations without entering them. In this way intermediate stations may communicate with each other; otherwise, they would have to remain idle while two exterior stations were communicating with each other. Of course, the larger the number of stations which can communicate with each other simultaneously, the larger must be the number of the wires.

When the instrument consists of two needles and two coils the alphabet may be made out somewhat in the following manner. Calling the left-hand needle No. 1, and the right-hand No. 2, and indicating one movement of either needle to the left by *l*, and one movement to the right by *r*, the combinations of movements which stand for the various letters of the alphabet are the following :—

	No. 1 Needle.	No. 2 Needle.		No. 1 Needle.	No. 2 Needle.
a	l l		o		r r
b	l l l		p		r r r
c	r l		q	r	l
d	l r		r	r	r
e	r		s	r r	r r
f	r r		t	r r r	r r r
g	r r r		u	l r	l r
h		l	v	r l	r l
i		l l	w	l	l
k		l l l	x	l l	l l
l		r l	y	l l l	l l l
m		l r	z	l	r
n		r			

Of course it is possible to form an alphabet with one needle and one wire only; the communication is not so rapid as with two wires and two needles, but the construction of the line is more economical, and the system is adapted for use between places of second-rate importance. Various alphabets and modes of signalling have been contrived with a view to celerity, and some of these are ingenious. We select one by the Rev. H. Highton, as described by Mr. E. Highton: a small slip of gold leaf inserted in a glass tube is made to perform part of the electric circuit of the line wire, and near it is a permanent magnet. When a current of electricity is passed along the line wire, the gold leaf is instantly deflected to the right or to the left according to the direction of the current. Now supposing the deflection of the gold leaf to the left signified the figure 1, and the deflection to the right the figure 3, we have the alphabet made up in the following manner: twice to the right, or 33, signifies A; twice to the left, once to the right, and once to the left, or 1131 = B; 311 = C; 133 = D; a single signal to the left, or 1 = E; thus acting on the correct principle of representing the letters of most frequent occurrence by the most rapidly executed signals; F 313, G 1133, H 113, I 31, J 3133, K 1331, L 331, M 1113, N 13, O 11, P 1111, Q 1313, R 333, S 111, T 3, U 131, V 1311, W 1333, X 3113, Y 3111, Z 3131. A motion to the left signifies "Do understand," and one to the right "Not understand." "Repeat" is expressed by 3331, and "Wait" by 3333.

Steinheil suggested the plan of receiving telegraphic signals by means of two bells, one muffled and the other free, to be struck by the needle or needles when deflected by two currents. This plan has been adopted by Sir Charles Bright on the relay system, with a local battery to supply the mechanical power required to strike the bells. This is used at the principal stations of the British and Irish Magnetic Telegraph Company. The transmitting instrument is a key invented by Highton, consisting of a couple of springs, one marked + and the other —, connected one with the earth and the other with the line. When these springs are at rest, or pressing upwards, the line and the earth are in connection with one another, and with the positive pole of the battery, the negative pole being insulated. When the earth-spring marked +, is pressed down by the finger, the earth connection is thrown on the negative pole, and the positive pole is left on the telegraph line, which thus receives a positive current. When the line-spring marked — is pressed down, the positive pole of the battery is left in connection with the earth, and the line is thrown into connection with the negative pole of the battery, and will thus receive a negative current. Now it is perfectly easy to make the two bells take the place of the gold strip, and calling the left-hand bell 1, and the right-hand bell 3, Highton's nomenclature becomes applicable. The receiving-clerk is seated between the two bells, and his ear being alone engaged in receiving the signals, he can write down the letters which they represent as easily as when one clerk is employed to watch the needle, and dictate the message to another who writes it down. Whether this system may not induce an increased amount of nervousness in the clerks employed, we are not able to say, but it is stated that the use of the ordinary needle telegraph is apt to produce nervous irritability in the clerks who are long employed upon it.

A considerable advance has recently been made in telegraphs in consequence of Professor Wheatstone's copious list of improvements in the whole of the telegraphic system, embodied in two patents dated 2nd of June, 1858, and numbered respectively 1239, 1241. We give these numbers in order that persons interested in the subject may the more readily procure the printed copies of the specifications, which are accompanied the one by six and the other by ten sheets of illustrative engravings. The basis of this invention is the Letter Telegraph of 1839, now called the *Universal Telegraph;* and it is so simple in its action that no training is required to use it; for the message may either be spelt out on a dial by bringing common letters opposite a fixed point, the necessary electrical currents being developed by an ordinary voltaic battery, or, still better, by induction from a permanent magnet. This telegraph is being rapidly adopted in London, where it forms the London District Telegraph; and also throughout the country by merchants and manufacturers, as a means of communication at their offices and establishments at a distance; also from one portion of a large warehouse to another, between the several heads of departments and the manager's room, through mills and public works, or wherever the constant transmission and receipt of intelligence is of importance. This system has been in use at the London Docks during the last few years, and also serves to communicate between the Houses of Parliament and her Majesty's printers in Shoe Lane. All we can pretend to do in this place is to give a brief outline of the more important features of this invention. It is described as Wheatstone's *Automatic Printing* Telegraph, and is capable of printing 500 letters per minute. The order and succession of the electric currents are determined by perforated bands of paper, somewhat after the manner of the cards in a Jacquard loom. The different letters are represented by groups of points, *fig.* 16, and these, when arranged for a message, are separated by smaller points, *fig.* 17, so as to prevent any mistake from the coalescence of adjacent letters, and the characters are printed without adding to the weight or causing any resistance in the moving parts of the electro-magnets. The invention consists of a new combination of mechanism, for the purpose of transmitting messages previously prepared through a telegraphic circuit, and causing them to be printed at a distant station. Long strips of paper are perforated by a machine, provided with apertures so grouped as to represent the letters of the alphabet and other signs (*fig.* 17): a strip thus prepared is placed in an instrument associated with a source of electric power, which on being set in motion moves it along, and causes it to act on two pins, in such a manner that when one of them is elevated the current is transmitted to the telegraphic circuit in one direction, and when the other is elevated it is transmitted in the reverse direction: the elevations and depressions of these pins are governed by the apertures and intervening intervals. These currents following each other indifferently in these two opposite directions act upon a writing instrument at a distant station in such a manner as to produce corresponding marks on a slip of paper (*fig.* 18) moved by appropriate mechanism.

Fig. 16.

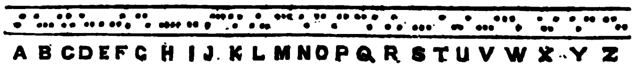


Fig. 17.

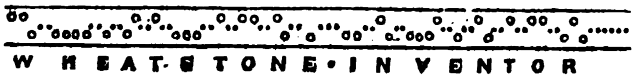
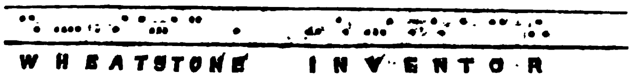


Fig. 18.



Each part of this telegraphic system is stated by the inventor to have its independent originality and to be capable of association with other forms of apparatus already known. The first of these inventions is an instrument called a *Perforator* for piercing the slips of paper in the order required to form the message. The slip passes through a guiding groove, at the bottom of which is an opening large enough to admit of the to-and-fro motion of the upper end of the frame containing three punches on a level. Each of these punches, however, may be separately elevated by the pressure of a finger-key, and at the moment of its elevation two different movements are successively produced. 1st, a clip is raised, which holds the paper firmly in its position; 2nd, the frame containing the three punches advances, by which the punch which is raised carries the ribbon of paper forward the proper distance; during the reaction of the key consequent on the removal of the pressure, the clip first fastens the paper and then the frame falls back to its normal position. The two external keys and punches are employed to make the holes, which grouped together represent letters and other characters, and the middle punch makes the holes which mark the intervals between the letters. A simple addition to the perforator enables a printed message which has been received to be retransmitted to a more distant station, without any translation or knowledge of the meaning of the message. The printed band passes between two rollers, one of which is moveable by a finger-screw, so as to cause the characters to pass successively before the eyes of the operator. The keys of the perforator are acted upon with the right-hand and the finger-screw with the left; as the characters successively appear the keys are pressed down in the order of the points of which the letters consist, an operation which scarcely requires any skill to perform, and which needs no change in the alphabet usually employed, the points at one side representing the short dashes, and those at the other side the long dashes, the order usually observed remaining the same.

The second apparatus is the *Transmitter*, which receives the strips of paper as prepared by the perforator and transmits the currents produced by the electro-motor in the order and direction corresponding to the holes perforated in the slip. This it effects by mechanism somewhat similar to that of the perforator. An eccentric produces and regulates three distinct movements. 1st, the to-and-fro movement of a small frame which contains a groove to receive the strip of paper, and carry it forward; 2nd, the rising and falling of a spring-clip, which holds the paper firmly during the receding motion, but allows it to move freely during the advancing motion; 3rdly, the simultaneous elevation of three wires placed parallel to each other, resting at one of their ends over the axis of the eccentric, and their free ends entering corresponding holes in the grooved frame. These three wires are not fixed to the axis of the eccentric, but each of them rests against it by the upward pressure of a spring, so that when a light pressure is exerted on the free ends of either of them it is capable of being separately depressed. When the slip of paper is not inserted, and the eccentric is in action, a pin attached to each of the external wires touches, during the advancing and receding motions of the frame, a different spring, and an arrangement is adopted by means of insulation and contacts properly applied, by which, while one of the wires is elevated and the other remains depressed, the current passes from the voltaic battery to the telegraphic circuit in one direction, and passes in the other direction when the wire before elevated is depressed, and *vice versâ;* but while both wires are elevated or depressed the passing of the current is interrupted. When the prepared slip of paper is inserted in the groove and moved forward, whenever the end of one of the wires enters an aperture in its corresponding row, the current passes in one direction, and when the end of the other wire enters an aperture in the other row it passes in the other direction. By this means the currents are made to succeed each other automatically in their proper order and direction, to give the requisite variety of signals. The middle wire only acts as a guide during the operation of the current. The wheel which drives the eccentric may be moved by the hand or by any motive power. Were the movements of the transmitter effected by machinery, then any number might be attended to by one or two assistants. Instead of a voltaic battery, a magneto-electric, or an electro-magnetic machine may be used as the source of electric power, in which case the transmitter and the magneto-electric, or electro-magnetic machine form a single apparatus, moved by the same power, and so adapted to each other that the currents are produced at the moments when the pins of the transmitter enter the apertures of the perforated paper. The transmitter requires only a single telegraphic wire.

The third apparatus is the *Recording* or *Printing apparatus*, which prints or impresses legible marks on a strip of paper corresponding in their arrangement with the apertures in the perforated paper. The pens or styles are elevated and depressed by their connection with the moving parts of electro-magnets. The pens are entirely independent of each other in their action, and are so arranged that when the current passes through the coils of the electro-magnet in one direction, one of the pens is depressed, and when it passes in the contrary direction the other pen is depressed; when the currents cease, light springs restore the pens to their usual elevated positions. The method of supplying the pens with ink depends on the principle that a liquid will not flow from a capillary opening unless it be electrified. Accordingly a shallow reservoir is made in a piece of metal, gilt within, and at the bottom of this reservoir are two capillary holes; the ends of the pens are placed immediately above these small holes, which they enter when the electro-magnets act upon them, carrying with them a sufficient charge of ink to make a legible mark on the strip of paper which passes beneath them. The motion of the strip is produced and regulated by apparatus similar to that employed in other register or printing telegraphs. Among the auxiliary improvements is a *Translator*, for converting the points or marks into the ordinary alphabetic characters. In this instrument there are nine finger-stops in two parallel rows of four each and the remaining one is placed separately. There is also a wheel on the circumference of which are placed at equal distances thirty types, representing the letters of the alphabet and other characters. Other mechanism is so disposed and connected thereto, that when the keys of the upper row are depressed the wheel is made to advance one, two, four, or eight steps or letters, and when the keys of the lower row are depressed the wheel advances two, four, eight, or sixteen steps respectively. By this arrangement, when the stops are touched successively in the order in which the points are printed on the paper, touching the first stop for one point, the first and second for two points, &c., and selecting the stops of the upper or lower row, according as the point is in the upper or lower row of the printed ribbon, the type wheel will be brought into the proper position for placing the letter corresponding to the succession of points over a ribbon of paper. The ninth stop, when it is pressed down, acts so as to impress the type on the paper, to cause the advance of the paper, in order to bring a fresh place beneath the type wheel, and subsequently to restore the type wheel to its initial position.

Professor Wheatstone remarks, that for the profitable working of a telegraphic line, the operator should manipulate as rapidly as is consistent with the correct transmission of the message; but this requires skill, even when the language of the despatch is known, but in a language unknown to the operator, or in cipher, he must proceed with caution and slowness. Under the new system the prepared messages can be transmitted with equal rapidity in whatever language or cipher they may be, and the perforated bands may be prepared at leisure, and even be subjected to the revision of a corrector.

Although this system is being extensively introduced in the metropolis and elsewhere, it does not interfere with the working of other companies, such as the Electric and International Telegraph Company, as it is now called, which transmits messages not only to all parts of the United Kingdom and Ireland and the Continent, but also by street lines between various parts of the metropolis, its central station in Lothbury gathering up the messages from its branch offices, and transmitting them to distant stations. Arrangements are made for sending messages at small cost between any of the metropolitan stations, of which at the time we are writing there are about 33. In addition to these stations there are wires between the Octagon Hall in the Houses of Parliament, and the St. James's Street Commercial Station, so that during the sitting of Parliament an abstract of the business of the two houses is made every half hour as it proceeds, and is posted up at the various club-houses, and also at the Italian Opera House. Members can thus know whether their presence is required in the House or not. The Opera House wire communicates with the Strand office, so that messages may be sent thence to all parts of the kingdom. The government wires proceed from Somerset House to the Admiralty, and thence to Portsmouth and Plymouth by the South-Western and Great Western railways.

The Portsmouth and Plymouth Dockyards also communicate by means of subterranean lines with the naval establishments at Deptford, Woolwich, Chatham, Sheerness, and with the Cinque Ports of Deal and Dover. These wires are worked independently of the Telegraph Company, and the messages are sent in cipher, the meaning of which is not known to the clerks who transmit the signals. There are also wires running from Buckingham Palace, and the chief Police Office in Scotland Yard, to the station at Charing Cross, and thence on to Lothbury, whilst the Post-Office, Lloyd's, the Stock Exchange, and the Corn Exchange, communicate directly with the Central Office.

At the present time almost every important town in Great Britain is furnished with means of telegraphic communication to other towns. As fast as any new railways, whether trunk or branch lines, are opened, so surely is the telegraph laid down; insomuch that the length of telegraph is nearly coincident with the length of rail. The exceptions to this rule are so few as scarcely to disturb the simplicity of the rule itself. From numerous places in the metropolis, messages are every day being quickly flashed to Aberdeen in one direction, to Liverpool in another, to Dover in a third, to Southampton in a fourth, to Plymouth, to Milford Haven, to Holyhead—indeed, to almost all our outports, and to nearly every inland town of any commercial pretensions. A system is everywhere acted on, that the principal railway stations shall at the same time be telegraph stations, some of the wires being for public use, and the others for railway use. The charges have been and are being gradually lowered, to the great advantage of all parties; and the messages now sent are of countless variety—the price of funds, the state of the markets, orders to purchase, the arrival of ships, what ships have just hove in sight, what ships have foundered, the receipt of important news, the Queen's speech, the result of elections, the divisions in a debate, the running of a race, the progress of the Court while travelling, the state of the weather, the direction in which a great storm is travelling, the verdict of an important trial, the sending for a doctor, the detection of a thief or murderer, inquiries after health, announcements of illness or of death, inquiries after lost luggage—these are only some of the open or confidential communications intrusted to the wires. Nor must we forget the various submarine cables, which although all have had occasional mishaps, yet taken collectively afford a remarkably complete series of channels through which messages may be exchanged between Great Britain and all the neighbouring countries; and now the English public hear with as little surprise of messages or *telegrams* (to use a new word, concerning which Greek scholars for a time carried on a fierce battle) brought under water as if brought on dry land.

On the continent of Europe we find telegraphic wires ramifying in all directions. Nations were never more struck with the wonders of the electric telegraph than on the occasion of the death of the Czar Nicholas in 1855. On the 2nd of March the Earl of Clarendon announced in the House of Lords that the Czar had died at St. Petersburg at one o'clock on that same day. Two distinct messages had been received, one *viâ* Berlin and the Hague, the other *viâ* Berlin and Ostend, both communicating a message telegraphed to Berlin from St. Petersburg, and all in four hours after the actual death. Not only have the dreary wastes of Russia been brought within the civilising influence of the electric wire, but lines in all directions have been laid, with or without regard to railways. Nearly all the chief cities in Europe are now linked together. Circuitous as is the route from London to Trieste, going through Belgium, Prussia, several minor German States, Saxony, Bohemia, Austria, and Istria, the connection is nevertheless complete; and telegrams are twice a-month transmitted to us relating to Indian affairs, brought to Trieste from Alexandria. Italy, in railways and in telegraphs, is in arrear of Austria; and Spain is lower on the list than Italy. Turkey, to the great astonishment of many of the Osmanlis, has been made a sharer in the fast-going, high-pressure operations of the age: she possesses an electric telegraph, extending from the Austrian frontier to Constantinople; and messages can now be flashed from London to the seat of the Ottoman empire. We have already glanced at other submarine lines, and must now conclude.

In sending messages in the United Kingdom by telegraph, either cipher may be used, or the ordinary signals known at the Telegraphic Office; but such is the jealousy of despotism, that on the continent of Europe cipher is never permitted, except by the governments for their own use.

An interesting use of the sub-way telegraph may be here noticed. In proportion as the use of Greenwich time has become familiar on all the English railways, so has it become important to ascertain this time with precision, in such a way as to enable all the station-clocks to be regulated thereby. This is one purpose of the time-ball in the Strand. The Electric Telegraph Company, the South-Eastern Railway Company, and the Astronomer Royal, have acted in conjunction in the establishment of this plan. A subterranean wire has been carried from the Observatory, through Greenwich Park, and across Blackheath to the Lewisham station of the North Kent Railway; thence to the London Bridge station; and thence to the Telegraph office in the Strand. At the top of this office has been erected a hollow shaft, up the interior of which the electric wire is carried, and a large light ball, capable of moving eight or ten feet vertically, slides easily up and down near the top of the shaft. At ten minutes before one o'clock each day the ball is raised nearly to the top of its shaft or spindle; and at five minutes before one it is raised quite to the top. At one o'clock precisely, exact to a single second, the great or master-clock at Greenwich Observatory puts in action a small piece of mechanism which sends an electric shock through the wire to the Strand; the wire at this end is connected with another piece of mechanism, which releases the ball and allows it to fall suddenly. The ball falls upon a kind of piston in an air-cylinder, so as to break the force of the concussion. As this ball is 130 feet above the level of the Thames; as it is six feet in diameter, exhibits bright colours, and falls through a considerable space, its descent can be seen for a great distance on all sides; and all who choose to regulate their clocks and watches by this standard can do so. An electric clock with four dials, illuminated at night, has been put up on a pillar in front of the office; it indicates Greenwich time at all hours. The various railway stations receive their time from the Strand office, which is the medium of communication from the Greenwich Observatory. There can be little doubt that these arrangements will contribute powerfully to the adoption of Greenwich time in church clocks and other public clocks. So useful is this considered to be, that a plan has been under consideration for erecting an electric time-ball on the summit of the South Foreland; the descent of such a time-ball at one o'clock each day, could be witnessed by the captains of ships many miles out in the Channel, who could regulate their chronometers by this means, as the time-ball would show Greenwich time. It was also proposed that the electric current should fire off a gun at the same time and place, so that the sound might be heard if the descent of the ball could not be seen. This proposal has actually been adopted at Edinburgh and elsewhere.

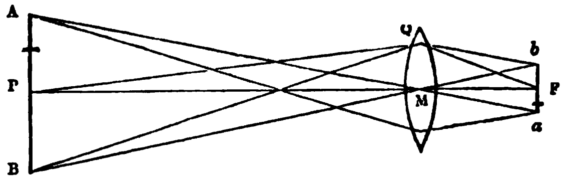
TELERYTHRIN. [LICHENS, COLOURING MATTERS OF.]

TELESCOPE (from the Greek *teléscopos*, τηλεσκόπος, "far-seeing"), an optical instrument consisting of a tube which contains a system of glass lenses having all their centres in one common axis, or a tube containing a metallic speculum in combination with such lenses: by either kind of instrument distant objects are caused to appear magnified, and more distinct than when viewed by the naked eye. Those which are constructed with glass lenses only are called *dioptric*, or *refracting*, and the others *catoptric*, or *reflecting* telescopes. In the former kind the rays in the pencils of light which come from every part of the object viewed are, by the first lens on which they are incident, made to converge so as to form an image at the focus of the lens. In some cases the rays in each pencil are intercepted by a second lens, and, by its refractive power, are made to enter the eye in parallel directions: in other cases, the rays, after having crossed each other at the place where the image is formed, fall in a divergent state upon a second lens, and by it are refracted so as to emerge from it in parallel directions. Frequently, however, the parallelism of the rays is effected by two or more lenses in addition to that, called the *object-glass*, by which the image was formed. In reflecting telescopes an image is formed by the reflection of the rays in the pencils of light coming from the object, after having impinged upon the concave surface of the speculum: in some cases this image is viewed through one glass lens or more, but frequently the rays, before or after forming the image, are reflected from a second mirror, and are subsequently transmitted to the eye through lenses.

By these instruments objects even in the remotest depths of space are rendered accessible to human vision; and terrestrial objects faintly visible in the distance are brought, as it were, close to the eye. In the hands of astronomers they were the means, almost immediately on being invented, of making more discoveries in the heavens than had been made during 5000 years previously; they form a valuable addition to the instruments employed by the mariner and the surveyor, and they will ever constitute the most agreeable companion of the traveller, by enabling him to distinguish, in every direction from him, objects which it might be difficult or impossible for him to approach.

In exhibiting the principles on which a telescope is constructed, it will be proper to commence with an explanation of the means by which the image of an object is formed at the focus of a lens or of a reflecting mirror. With respect to a lens, if it be of the kind called *convex* [LENS], the rays in the pencils of light which proceed from every part of an object, as A P B, *fig.* 1, in passing through the lens, supposing the latter to have a proper degree of curvature, are made to converge by the refracting power of the glass at points, as *a*, F, and *b*, and the assemblage of such points constitutes an *image* of the object: if a screen were placed at F perpendicularly to the axis P F, the object would be represented on it, in an inverted position.

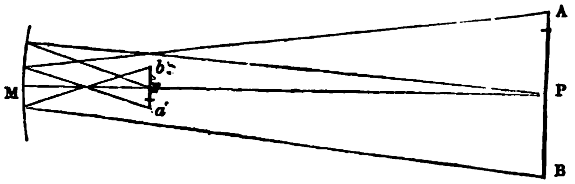
Fig. 1.



If the lens were of a concave form, the rays in the several pencils, after passing through it, would be made to diverge from one another, and consequently no image could be formed: yet if the directions of the rays, after refraction, were produced backwards, they would unite between the lens and the object, in points corresponding to those which constitute the image formed by the convex lens.

If the rays in the pencils of light proceeding from different points, A, P, B, *fig.* 2, in an object are reflected from the surface of a concave mirror, supposing the latter to have a certain degree of curvature, those rays will unite in as many points, *a*, F, and *b*, and form an image of the object. If a screen were placed at F the object would be represented on it, in an inverted position. The rays in each pencil reflected from the surface of a *convex* mirror are made to diverge from each other; and in that case no image is formed.

Fig. 2.

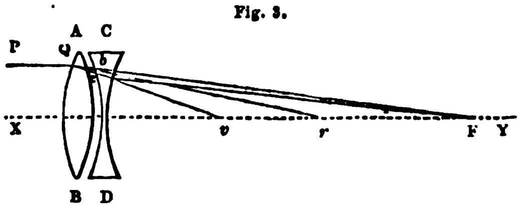


Now, if the object A B be so remote that, in each pencil, the rays incident upon a lens may be considered as parallel to one another, the point F is called the *principal focus;* and in the article LENS, there will be found a collection of formulæ for the reciprocals of the focal lengths of lenses of all the different kinds; it being understood that the diameter of the lens is small, which is generally the case with telescopes, and that the light is homogeneous. But, since all light is not of one kind, and a lens acts like a prism in causing in each pencil the rays of the differently coloured light to diverge from one another, it follows that each of the coloured lights will form its *own image* at its proper focus; and the image formed by light of one kind being seen by the eye along with the images formed by light of the other kinds, the representation of an object when formed by a single lens appears to be indistinct and surrounded by a coloured fringe. [ACHROMATIC; LIGHT; DISPERSION.] It may be observed that the principal focus of any lens, with respect to each colour, may be obtained from the formulæ in LENS, by substituting in them the value of μ (the index of refraction) for the given kind of light.

Thus, in an optical instrument, in addition to the distortion of the image arising from the sphericity of the lens, there is an indistinctness caused by the dispersion of the different colour-making rays; and, in a good telescope, it is requisite that both of these imperfections should as far as possible be removed. The *chromatic aberration*, as the dispersion of the colour is called, constitutes by far the greater evil of the two, for Newton has shown that it exceeds the former nearly in the ratio of 5449 to 1; but fortunately it is that which, to an extent sufficient for practical purposes, admits of being easily corrected.

Since different kinds of glass have different degrees of dispersive power, it is evident that the chromatic aberration may be diminished, if not wholly removed, by causing the light to pass through two lenses of different kinds of glass, and of such forms that they may refract the rays in each pencil in opposite directions. The object-glass of a telescope when so formed is said so be *achromatic*, and the manner in which the effect is produced may be understood from the following description. Let P Q be the direction of a pencil of compound light incident on the first surface of the convex lens A B, *fig.* 3, in a direction parallel to the common axis, X Y, of the two lenses. By the refractive power of this lens (*crown* glass) the red rays in the pencil would, if no object were interposed, proceed in the direction Q *b*, meeting X Y in *r*, and the violet ray in the pencil would proceed in the direction Q *c*, meeting the axis in *v*. But the refractive power of the concave lens C D (*flint* glass) acts, from its form, in a direction contrary to that of the convex lens, causing the rays either to diverge from the axis X Y, or to meet it in points beyond *v* and *r*, towards Y: suppose the curvature of this lens to be such that the red rays in the pencil P Q would, after refraction in both lenses, meet the axis in F (the ray Q *b* *r* taking the direction *b* F); then the dispersive power of this kind of glass exceeding that of the other kind, the violet rays in the refracted pencil will tend farther away from the axis than the red rays do, and thus will tend towards the latter; the ray Q *c v*, for example, taking the direction *c* F. It is conceivable, therefore, that the curvatures of the surfaces of the lenses may be such that, in each incident pencil, the red and violet rays (the extreme rays of the spectrum) shall, after refraction, unite at the place of the image; and thus the fringe due to these two colours may be destroyed.

Fig. 3.



If the two kinds of glass dispersed the different colour-making rays in the same proportions, their contrary refractions would cause all the colours to be united on the image formed at F: no two kinds of glass have, however, been as yet discovered which possess this property; and therefore the red and violet images only are united: fortunately, in uniting the extreme rays of the spectrum, the others are brought so near together, that for ordinary purposes the image is as free from colour as can be desired.

From the description just given it will be evident that the place F, of an image in which the dispersion of the red and violet rays is corrected, may be determined on obtaining, from the common theorems of optics, algebraic expressions for the focal lengths of the compound lens for each of those kinds of light, and making the expressions equal to one another. Thus, supposing R and S to be the radii of the curve surfaces of a double convex lens of crown glass, and μ the index of refraction for light of one kind (red, for example); supposing again that the rays in the pencils of incident light are parallel to one another and pass through the lens very near the axis; then, by a fundamental theorem in optics we have, F being the distance from the focus to the lens, which is moreover without thickness,

$$F = \frac{R \,.\, S}{R + S} \cdot \frac{1}{\mu - 1}:$$

but since, in the present case, the lens may be supposed to be isosceles ($R = S$), we have $F = \frac{R}{2(\mu - 1)}$.

In like manner the focal length F′, of a double concave lens of flint glass, R′ being the radius of each surface, and μ' the index of refraction for red rays, is equal to $-\frac{R'}{2(\mu' - 1)}$, the rays being incident near the axis.

Hence, by a fundamental theorem in optics,

$$\frac{R'}{\mu' - 1} - \frac{R}{\mu - 1} : \frac{R'}{\mu' - 1} :: \frac{R}{2(\mu - 1)} : \frac{RR'}{2\{R'(\mu - 1) - R(\mu' - 1)\}}$$

and this last term is the focal length of the compound lens for red rays. Its reciprocal is equal to $\frac{2(\mu - 1)}{R} - \frac{2(\mu' - 1)}{R'}$, which, in the algebraic sense, is the sum of the reciprocals of the focal lengths of the separate lenses.

On writing $\mu + \delta\mu$, and $\mu' + \delta\mu'$, in place of μ and μ' in the last expression, we have for the reciprocal of the focal length of the compound lens for violet rays,

$$\frac{2(\mu + \delta\mu - 1)}{R} - \frac{2(\mu' + \delta\mu' - 1)}{R'}.$$

In an achromatic telescope the focal lengths of the compound lens for red and violet rays are to be equal to one another; and it is evident that this condition will be fulfilled when $\frac{\delta\mu}{R} - \frac{\delta\mu'}{R} = 0$. From this equation we have $R : R' :: \delta\mu : \delta\mu'$; then, dividing the antecedents by $\mu - 1$ and the consequents by $\mu' - 1$, we have [DISPERSION] the ratio of the focal lengths of the two lenses equal to that of the dispersive powers of the two kinds of glass; and hence, the focal length of the compound lens being assumed at pleasure, those of the separate lenses, consequently the radii of their surfaces, may be obtained.

In order to diminish the spherical aberration, the object-glasses of achromatic telescopes frequently consist of three lenses, of which the first and third are of the kind called double convex, and are formed of crown glass, while the second is double concave, and made of flint glass. In this case, since the index of refraction is the same for the third lens as for the first, if the radius of each surface of the third lens be R″, the reciprocal of the principal focal lengths of the separate lenses for red rays will be,

$$\frac{2(\mu-1)}{\mathrm{R}},\ -\ \frac{2(\mu'-1)}{\mathrm{R}'},\ \text{and}\ \frac{2(\mu-1)}{\mathrm{R}''};$$

these being added together, their sum will be the reciprocal of the focal length of the compound lens for one kind of light. On substituting in the above terms, $\mu+\delta\mu$ for μ, and $\mu'+\delta\mu'$ for μ', in order to obtain the reciprocals of the focal length for violet rays, we shall have, when the chromatic aberration is corrected,

$$\frac{\delta\mu}{\mathrm{R}} - \frac{\delta\mu'}{\mathrm{R}'} + \frac{\delta\mu}{\mathrm{R}''} = 0,\ \text{or}\ \mathrm{R}'\left(\frac{1}{\mathrm{R}} + \frac{1}{\mathrm{R}''}\right) = \frac{\delta\mu'}{\delta\mu}.$$

But $\frac{\delta\mu'}{\delta\mu}$ is known from tables of the refractive indices for different kinds of glass: therefore if any convenient relation between the radii of two of the lenses be assumed, the values of all the radii, and consequently the focal lengths of the several lenses, may be found.

The investigation of formulæ for the correction of the spherical aberration is a process of some labour, and is scarcely a fit subject except for a mathematical work: it is treated with great perspicuity in Robison's 'Mechanical Philosophy,' vol. iii., from which the subjoined theorem is borrowed, the notation only being changed for that which has been adopted above; and also in the articles LENS and SPECULUM. If a compound object-glass consists of one double convex lens of crown glass and a double concave lens of flint glass, and a ray of light be incident upon the anterior surface of the former in a direction parallel to the axis, at a distance from thence, which is expressed by e; the distance from the lens, of the point at which the ray after refraction will meet the axis, is $f-f^2(q+q')$, where f is the focus for parallel rays infinitely near the axis, and may be found as above, and $f^2(q+q')$ is the aberration. Here, neglecting the thickness of the lenses and the interval between them,

$$q = \frac{\mu-1}{\mu}\left\{\frac{\mu^3}{n^3} - \frac{2\mu^2+\mu}{\mathrm{R}n^2} + \frac{\mu+2}{\mathrm{R}^2 n}\right\}\frac{e^2}{2},\ \text{and}\ n = \frac{\mathrm{RS}}{\mathrm{R}+\mathrm{S}};$$

(R and S being the radii of the two surfaces of the convex lens), and

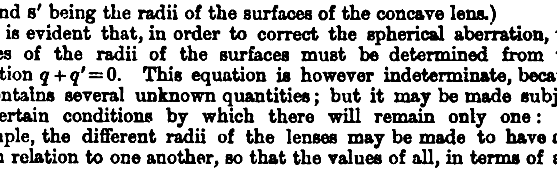
$$q' = \frac{\mu'-1}{\mu'}\left\{\frac{\mu'^3}{n'^3} - \frac{2\mu'^2+\mu'}{\mathrm{R}'n'^2} + \frac{\mu'+2}{\mathrm{R}'^2 n'^2} + \frac{3\mu'^2+\mu'}{\mathrm{F}\,.\,n'^2} - \frac{4(\mu'+1)}{\mathrm{F}\,.\,\mathrm{R}'n'}\right\}\frac{e^2}{2}:$$

where F is the principal focus of the convex lens, and $n' = -\frac{\mathrm{R}'\mathrm{S}'}{\mathrm{R}'+\mathrm{S}'}$; (R′ and S′ being the radii of the surfaces of the concave lens.)

It is evident that, in order to correct the spherical aberration, the values of the radii of the surfaces must be determined from the equation $q+q'=0$. This equation is however indeterminate, because it contains several unknown quantities; but it may be made subject to certain conditions by which there will remain only one: for example, the different radii of the lenses may be made to have any given relation to one another, so that the values of all, in terms of any one, may be substituted for them. In the values of q and q' the terms represented by n and n' are respectively equal to half the radii of equivalent isosceles lenses; and it has been shown, in the investigation concerning the chromatic aberration, that these are to one another as $\delta\mu$ to $\delta\mu'$; consequently $n'=n\frac{\delta\mu'}{\delta\mu}$, and therefore n' is known in terms of n. If again it be supposed that R′ = S, or that the nearest surfaces of the convex and concave lenses have equal curvatures, the value of R may be found from the equation $q+q'=0$, in terms of n, by a quadratic equation.

Sir John Herschel, in a paper on the aberration of compound lenses and object-glasses ('Phil. Trans.,' 1821), has also investigated formulæ for the values of the chromatic and spherical aberrations; and M. Littrow, of Vienna, setting out with Euler's formula for spherical aberration ('Dioptrica,' tom. iii., 1769), and introducing in it the values of the focal lengths of two lenses so that the former aberration may be corrected, has obtained two equations from which the radii of the four surfaces may be determined by such conditions as may be thought convenient. ('Memoirs of the Astron. Soc.,' vol. iii., part 2). In solving the problem relating to the determination of th[illegible] four radii, Professor Littrow uses a method which possesses some facilities for computation, and on that account it has been adopted in the following process.

Fig. 4.



The radii of the surfaces of the first lens may be determined on the supposition that the whole refraction of light in passing through the lens is a minimum; that is, that the incident and emergent rays make equal angles with the surfaces, or with those radii. Thus let a ray PQ, *fig.* 4, be incident on the first surface in a direction parallel to the axis XY of the lens, and infinitely near it; and RQT being the radius (= R) produced, of that surface let the angle PQT of incidence be represented by a; then $\mu : 1 :: a : \frac{a}{\mu}$ (= RQF, the angle of refraction at that surface). But if R′QT′ be the radius (= S) produced, of the second surface; then, in the triangle R′QR, neglecting the thickness of the lens and substituting arcs for their sines, $\mathrm{S} : \mathrm{R} :: a : \frac{\mathrm{R}}{\mathrm{S}}a$; and $\frac{\mathrm{R}}{\mathrm{S}}a + a - \frac{a}{\mu}$ (= T′QF) is the angle of incidence on the second surface: and, by optics, 1 is to μ as this last angle is to $\frac{a\mu\mathrm{R}}{\mathrm{S}} + a(\mu-1)$, the angle of refraction (= T′QF′) at the second surface. But by hypothesis, this angle is to be equal to a; therefore $\frac{\mathrm{R}}{\mathrm{S}} = \frac{2-\mu}{\mu}$. Again, by optics $\frac{\mathrm{RS}}{\mathrm{R}+\mathrm{S}}\cdot\frac{1}{\mu-1}$ is equal to the focal length of the lens; and supposing this to be equal to unity, we obtain $\frac{\mathrm{R}}{\mathrm{S}} = \frac{\mathrm{R}-\mu+1}{\mu-1}$: equating this last term with $\frac{2-\mu}{\mu}$ above, we get $\mathrm{R} = \frac{2(\mu-1)}{\mu}$ whence $\mathrm{S} = \frac{2(\mu-1)}{2-\mu}$. Therefore the two radii are found on the supposition that the focal distance of the lens is unity.

Now PQT being the angle of incidence as above, and QF the direction of the ray after one refraction, we have by optics, $\sin \mathrm{RQF} = \frac{\sin \mathrm{PQT}}{\mu}$; and by trigonome in the triangle RQF,

$$\mathrm{RF} = \mathrm{R}\,\frac{\sin \mathrm{RQF}}{\sin \mathrm{P'QF}},\ \text{and}\ \mathrm{MF} = \mathrm{R}\left(\frac{\sin \mathrm{RQF}}{\sin \mathrm{P'QF}} + 1\right);$$

also, representing the thickness MN of the lens by t,

$$\mathrm{R'F} = \mathrm{R}\left(\frac{\sin \mathrm{RQF}}{\sin \mathrm{P'QF}} + 1\right) + \mathrm{S} - t.$$

Then, by trigonometry, in the triangle R′QF,

$$\text{we get}\ \frac{\mathrm{SF}+\mathrm{S}-t}{\mathrm{S}}\sin \mathrm{P'QF} = \sin \mathrm{T'QF};$$

consequently by optics, $\frac{\mathrm{SF}+\mathrm{S}-t}{\mathrm{S}}\,\mu \sin \mathrm{P'QF} = \sin \mathrm{T'QF'}$ or the sine of the angle of refraction at the second surface.

Now $\mathrm{T'QF'} - \mathrm{T'QF} + \mathrm{P'QF} = \mathrm{QF'M}$, or the angle which the second refracted ray makes with the axis of the lens: but by trigonometry, in the triangle R′QF′, we have

$$\mathrm{R'F'} = \mathrm{S}\,\frac{\sin \mathrm{T'QF}}{\sin \mathrm{P'QF}};\ \text{whence}\ \mathrm{NF'} = \mathrm{S}\left(\frac{\sin \mathrm{T'QF}}{\sin \mathrm{P'QF}} - 1\right).$$

Suppose next a double concave lens, the centres of whose surfaces are at R″ and R‴, and whose radii are R′ and S′, to be applied to the convex lens on the side N: then, neglecting the thickness of the concave lens and the distance between the two, and supposing QF″, QF‴ to be the directions of the ray of light after the third and fourth refractions respectively, we have in the triangle R″QF′, by trigonometry,

$$\frac{\mathrm{R'}+\mathrm{S'F'}}{\mathrm{R'}}\sin \mathrm{P'QF'} = \sin \mathrm{T''QF'},$$

or the sine of incidence on the first surface of the second lens; and by optics,

$$\frac{\mathrm{R'}+\mathrm{S'F'}}{\mathrm{R'}\mu'}\sin \mathrm{P'QF'} = \sin \mathrm{T''QF''}.$$

But $\mathrm{P'QF'} - (\mathrm{T''QF'} - \mathrm{T''QF''}) = \mathrm{P'QF''}$; and in the triangle R″QF″, by trigonometry, we have

$$\mathrm{R''F''} = \mathrm{R'}\,\frac{\sin \mathrm{T''QF''}}{\sin \mathrm{P'QF''}};$$

wherefore $\mathrm{NF''} = \mathrm{R'}\left(\frac{\sin \mathrm{T''QF''}}{\sin \mathrm{P'QF''}} - 1\right)$; and considering NR‴ to be equal to S′, R‴F″ will be equal to NF″ − S′.

Again, in the triangle R‴QF″, we have by trigonometry,

$$\sin \mathrm{R'''QF''} = \frac{\mathrm{NF''}-\mathrm{S'}}{\mathrm{S'}}\sin \mathrm{QF''N}$$

for the sine of incidence on the fourth surface; therefore, by optics,

$$\frac{\mathrm{NF''}-\mathrm{S'}}{\mathrm{S'}}\,\mu' \sin \mathrm{QF''N} = \sin \mathrm{R'''QF'''},$$

the sine of refraction at the fourth surface; then

$$\mathrm{QF''N} - (\mathrm{T'''QF''} - \mathrm{T'''QF'''}) = \mathrm{P'QF'''},\ \text{or}\ = \mathrm{QF'''N};$$

and by trigonometry, in the triangle $QF'''R'''$, we have

$$R'''F''' = S'\,\frac{\sin R'''QF'''}{\sin QF'''N},\ \text{and}\ NF''' = S'\left(\frac{\sin R'''QF'''}{\sin QF'''N} + 1\right),$$

the focal distance of the compound lens.

These values being reduced to what they become when the incident ray PQ is infinitely near the axis of the lenses; that is, when the angles are substituted for their sines, there may be obtained

$$\frac{R}{MF} = \frac{\mu - 1}{\mu},\ \frac{S}{NF'} = \frac{\mu S}{MF - t} + \mu - 1,$$

$$\frac{R'}{NF''} = \frac{R'}{NF'\mu'} + \frac{\mu' - 1}{\mu'}\ \text{and}\ \frac{S'}{NF'''} = \frac{S'\mu'}{NF''} + \mu' - 1.$$

By means of these equations, eliminating the quantities MF, NF', and NF'', and neglecting powers of t above the first, there may be obtained a value of $\frac{1}{NF'''}$: then differentiating this value with respect to to μ, μ', and NF''', and making the resulting value of the differential of NF''' equal to zero (which is a condition necessary in order that the chromatic dispersion may be corrected for rays near the axis), there may be obtained a value of $\frac{1}{R'} + \frac{1}{S'}$. Again on substituting $\frac{2(\mu - 1)}{\mu}$ for R, and $\frac{2(\mu - 1)}{2 - \mu}$ for S, as above found, there will result

$$\frac{1}{NF'''} = 1 - \frac{\mu' - 1}{\mu - 1}\left\{1 + \tfrac{1}{4}(\mu + 1)t\right\}\frac{d\mu}{d\mu'} + \tfrac{1}{4}\mu t,\ \text{and}$$

$$\frac{1}{R'} + \frac{1}{S'} = -\frac{1}{\mu - 1}\left\{1 + \tfrac{1}{4}(\mu + 1)t\right\}\frac{d\mu}{d\mu'}.$$

Now the value of NF''' may be directly computed from the formulæ first investigated; afterwards assuming different values of R', and substituting them in the last equation. let the corresponding values of S' be found. With these values of S' find corresponding values of $S'\left(\frac{\sin R'''QF'''}{\sin QF'''N} + 1\right)$; that is, of NF''', and proceeding according to the usual methods of trial and error, there will at length be found a value of NF''' agreeing with that which was computed by the direct process: the four radii will then, consequently, be determined.

Investigations relating to the dispersion of light, and rules for computing the radii of curvature for achromatic object-glasses, will also be found in an essay by Mr. P. Barlow of Woolwich, printed in the 'Philosophical Transactions' for 1827.

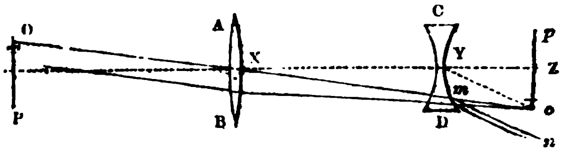
Though on thus uniting the red and violet light by lenses of crown and flint glass the chromatic dispersion is in a great measure corrected, yet when the image is examined, it is found to be surrounded by a green-coloured fringe. The difficulty of procuring flint glass of sufficient purity is also a serious impediment to the perfection of achromatic lenses for telescopes. The steps that have from time to time been taken to remedy this evil are noticed in the following article on the history of the telescope, [TELESCOPE, HISTORY OF,] but we may here mention that in the 'Transactions' of the Royal Society of Edinburgh, 1791, there is given an account of some experiments made by Dr. Blair, from which he was led to the discovery of the fluid medium, which, being applied between lenses of crown glass, renders the compound lens completely achromatic. By adding liquid muriatic acid to chloride of antimony, or sal ammoniac to chloride of mercury, he succeeded in obtaining a spectrum in which the coloured rays in each pencil followed the same law of dispersion as takes place in crown glass. Therefore, confining a small quantity of either of these liquids between the convex surfaces of two plano-convex lenses, or between those of a plano and a convex meniscus lens, of crown glass, Dr. Blair obtained an object-glass in which the chromatic aberration was entirely destroyed; and he is said to have thus constructed one of 9 inches focal length, and as much as 3 inches in diameter or aperture. Object-glasses so made were for some years on sale in London; but either from the crystallisation of the fluids, or the negligence of the artists in compounding them, the telescopes became imperfect, and gradually fell into disuse.

Dr. (Sir David) Brewster, in his 'Treatise on New Philosophical Instruments,' recommends the employment of sulphuric acid and oil of cassia for the composition of fluid lenses, by which the secondary spectrum may be destroyed; the acid being, of all known substances, that which exerts the greatest, and the oil that which exerts the least, action on the green-coloured rays. The correction of the chromatic dispersion by means of fluids was also attempted by Mr. Barlow, as noticed in the following article. But probably from imperfections in the forms of the glasses, the images of objects were found to be not well defined; and the construction, in consequence, has not been adopted.

The image formed by the great speculum of a reflecting telescope is free from the inconveniences attending the chromatic aberration of light; for the angles of incidence being equal to those of reflection, in any pencil coming from a point in an object, all the rays will converge to one point at the place where the image is formed. If the surface of the speculum were that which is formed by the revolution of a parabola about its axis, then all the rays in any pencil proceeding from a very remote object, as one of the celestial bodies, and being incident on the speculum in a direction parallel to the axis, would, by the nature of the parabola, converge accurately in the focus of the curve; and on this account, an effort is always made to give to the reflecting surface of the speculum a paraboloidal figure. The advantage does not, however, hold good with the pencils which fall on the mirror in directions oblique to the axis; and therefore that figure is of less importance, when the telescope is to be used for viewing terrestrial objects, than when it is to be employed for astronomical purposes; for then, on account of the great distance of the objects, the several pencils of light fall on the mirror with a very small obliquity to its axis.

The telescope invented by Galileo consisted of one convex lens, A B, *fig.* 5, and of a concave lens, C D; the distance between them being equal to the difference between the focal lengths of the two lenses. In this instrument, if the object O P were so remote that the rays in each pencil of light might be considered as parallel to one another, there would be formed at its principal focus an inverted image (*o p*) of that object by the union of the rays in each pencil in one point; then the concave lens being placed between A B and that image, in such a situation that its principal focus may coincide with the place of that image, the rays in each pencil will, by the refracting power of the lens, be made to emerge parallel to one another; and in this case, by the optical properties of the eye, distinct vision is obtained.

Fig. 5.

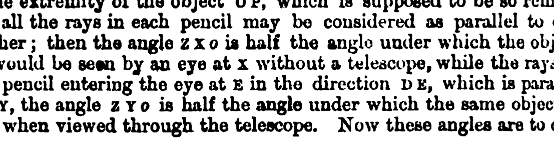


The line O X *o* is the axis of the pencil of light from O; and, as this passes through the centre X of the lens A B without refraction, the angle Z X *o* is equal to half the angle under which O P would be observed by an eye at X when no telescope is interposed, while (*m n* parallel to Y *o* being the direction of a ray in that axis after refraction in C D) Z Y *o* is half the angle under which O P is seen in the telescope: the ratio between these angles is therefore the measure of the magnifying power of the telescope; and since the angles are to one another as Y Z is to X Z, nearly, it follows that $\frac{XZ}{YZ}$ nearly expresses the magnifying power.

This is the construction of what is called an *opera glass*; and the Galilean telescope is now used chiefly for viewing objects within a theatre, or an apartment, since if considerable magnifying power were given to it the extent of the field of view would be very small.

A simple telescope may also be constructed by means of two convex lenses, *fig.* 6, which are placed at a distance from one another equal to the sum of their focal lengths. For the image being formed at the focus Z, of the lens A B, which is nearest to the object, as in the Galilean telescope, and being supposed to be a plane surface, the light also being supposed to be homogeneous, the rays of each pencil, after crossing at the focus and proceeding from thence in a divergent state, on being allowed to fall upon the surface of the second lens, C D, may be refracted in the latter so as to pass out from thence in parallel directions; and consequently distinct vision of the object may be obtained by an eye situated so as to receive the pencils.

Fig. 6.

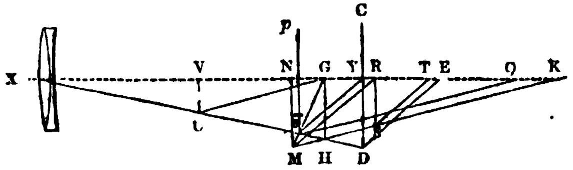


If X *o* be the direction of the axis of a pencil of light coming from O, one extremity of the object O P, which is supposed to be so remote that all the rays in each pencil may be considered as parallel to one another; then the angle Z X *o* is half the angle under which the object O P would be seen by an eye at X without a telescope, while the rays of that pencil entering the eye at E in the direction D E, which is parallel to *o* Y, the angle Z Y *o* is half the angle under which the same object is seen when viewed through the telescope. Now these angles are to one another nearly as Z Y to Z X; therefore $\frac{ZX}{ZY}$ will express nearly the magnifying power of the instrument. As the pencils of light from O and P cross the axis of the eye at E before they are united on the retina, the image of the object O P is formed in the eye in a position contrary to that which is formed when the object is viewed without the telescope; therefore, on looking through the latter, the object O P appears to be inverted.

But the image formed at *op*, instead of being a plane, is nearly on a portion of a spherical surface whose centre is at X; and, on the other hand, in order that the rays in each pencil may after refraction in C D be parallel to one another, they ought to diverge from a point nearly in the surface of a sphere whose centre is at Y, the two spherical surfaces being in contact at Z: consequently when the distance between the lenses is such that the crossing of the rays in a pencil parallel to the axis takes place exactly at Z, the crossing z in one of the oblique pencils will be at a certain distance from the point z', at which it ought to be to permit the rays in it to go out of C D parallel to one another; the rays of the pencils which proceed from the margin of the object will not then emerge parallel to one another, and consequently that margin will not be distinctly seen. Moreover, from the unequal refrangibility of the different kinds of light, the rays in each pencil will be decomposed in passing through the lens C D, so that though the chromatic aberration were perfectly corrected in the image at *p o*, it would exist in the image which is formed in the eye by the rays emerging from C D.

The spherical aberration can only be diminished by diminishing the inclination at which the rays in the marginal pencils fall upon the surface of the lens after having crossed at the focus of the object-glass; that is, by using a lens of less convexity or of greater focal length; adding a second eye-glass in order finally to render the rays in each pencil parallel to one another. Thus, if it be required to preserve the same magnifying power and field of view as might be obtained with any single eye-glass; let, as before, X, *fig.* 7, be the place of the object-glass, *o p* the image formed by it, and let C D be the place of the single eye-glass: then draw a line *o* Q so as to bisect the angle D *o* Y, which may be considered as the whole refraction produced by the lens C D: let G, on the right or left of *o p*, be the assumed place of what is called the *field-glass*, and draw G H perpendicular to X Y, the axis of the telescope, meeting X D in H; also through H draw M H K parallel to *o* Q, cutting G *o*, or G *o* produced, in M: again draw M N perpendicular to the axis of the telescope, and M R parallel to *o* Y; also draw R S perpendicular to the axis. Lastly, draw G U parallel to Q Q to meet X *o* in U, and U V perpendicular to the axis. Then, from the principles of optics, if a lens be placed at G, having its focal length equal to G V, and another at R, whose focal length is R N; the ray X *o* H will by refraction in the first lens take the direction H S, and by refraction in the second lens it will take the direction S T parallel to *o* Y or D E: thus the present visual angle S T R will be equal to D E Y, which was obtained with the single eye-glass.

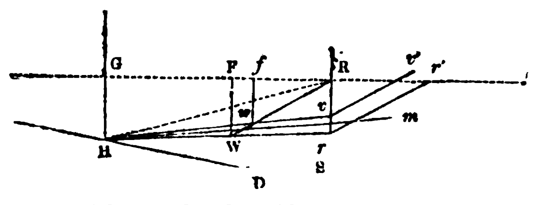
Fig. 7.



This is called the *Huyghenian eye-piece*, and it is that which is generally used for astronomical telescopes: the object seen through it is inverted, as in the last-mentioned telescope.

If the places G and R of the two eye-glasses are given (G H being very near *op*; its focal length being also known), and it be required to find the focal length of R S so that the red and violet rays in each pencil may emerge from it parallel to one another, that length might be determined in the following manner. In a pencil of rays crossing each other at H, *fig.* 8, let H*m* be the direction of a mean ray, and H*r*, H*v* those of a red and a violet ray; these last will make with one another an angle equal to about $\frac{1}{27}$ of the angle D H*m*, which may be supposed to be known. Now, by optical principles, if these rays are to emerge from R S in directions parallel to one another, the focal lengths of the lens for red and violet rays, namely, R F and R*f* must be to one another as 28 to 27, and the foci F and *f* must be in places determined by perpendiculars drawn to the axis from points W and *w*, in which the line R W supposed to be drawn parallel to *rr'* or *vv'*, meets H*r* and H*v*; that is, by finding the position of a line to be drawn from R to cut the given lines H*r*, H*v*, so that R W may be to R*w* as 28 to 27. For this purpose, having drawn the straight line H R, the angles R H W, R H*w* will be known; let them be represented by a and b; also let the angle H R W be represented by θ: then by trigonometry we shall have, after a few reductions, 27 cotan. $a - 28$ cotan. $b =$ cotan. θ.

Fig. 8.



In order to afford a view of objects in the same position as they appear to have when seen by the naked eye, a telescope may be formed with three lenses besides the object-glass. In the construction of this instrument, if attention is paid only to the rays which suffer a mean refraction, the first eye-glass, or that which is nearest to the object-end of the telescope, may be placed between the image formed by the object lens and the eye, with the foci of the two lenses in coincidence; by this means the rays in each pencil will emerge from the first eye-glass in directions parallel to one another, those of the pencils which are oblique to the axis of the telescope crossing each other at some point in the latter axis. A second eye-glass is then placed at any convenient distance from the former, beyond the place where the oblique pencils cross each other; and by this lens a second image is formed in a position contrary to that which is formed by the object lens. Lastly, the third lens being placed between this image and the eye at a distance from the former equal to its focal length, the rays in the several pencils will emerge parallel to one another, and an erect image of the object will thus be formed in the eye.

The ratio between the angles under which an object would be seen by the naked eye, and that by which it is seen in the telescope, is compounded of the ratios of the focal lengths of the several lenses; thus, if F be the focal length of the object-lens, f', f'', f''' those of the eye-lenses, reckoned in order towards the eye, the expression $\frac{F\,.\,f''}{f'\,.\,f'''}$ will denote the magnifying power.

But both the spherical aberration and the chromatic dispersion in such a telescope are very considerable; and before the invention of the achromatic object-glass, Mr. Dollond endeavoured to diminish the former by an eye-tube consisting of five lenses disposed so as to divide the bendings of the pencils nearly equally between them. Such telescopes are not now used; and Mr. Dollond succeeded at length in constructing telescopes with four eye-glasses, from which both distortion and colour are removed as much perhaps as a removal is possible.

This is accomplished by placing the first eye-glass beyond the image formed by the object-glass, and at a distance from it less than the focal length of that eye-glass: by this disposition the rays of mean refrangibility in each pencil which diverges from the image are not, after refraction, parallel to one another, but go on with diminished divergency. A little way beyond the place where the axes of the oblique pencils cross the axis of the telescope there is placed the second eye-glass, which is of such focal length that the mean refrangible rays in each pencil, after passing through it, meet in a point, and thus a second image of the object is formed near the eye: the use of these two lenses, therefore, is to cause the second image to be formed by a gradual convergence of the rays in each pencil. But the several pencils of rays are intercepted by the third eye-glass (commonly called the field-glass), and the second image is thereby formed rather nearer to the first than it would be without such field-lens: from this image the rays in each pencil diverge, and by the refractive power of the fourth eye-glass they are made to enter the eye in parallel directions: thus distinct vision of the external object is obtained. The field-glass might have been placed between the eye and the second image, as in the Huyghenian eye-piece before described; but the aberration arising from the spherical form of the glasses is a little less by the construction just mentioned.

Now, in each pencil, the red and violet rays which had been united at the image formed by the object-glass, and which there crossed each other, go on from thence diverging from each other till, on the opposite side of the axis of the telescope, they fall upon the surface of the second eye-glass: after passing through this lens, the violet ray, which is always more refracted than the red ray, gradually converges towards the latter, and at length meets it in some place short of that at which the rays of mean refraction unite to form the second image. The practice is to fix the third or field-glass exactly or nearly at the place where the red and violet rays so unite in all the pencils; for the different coloured rays crossing each other in that place, they are finally, by the refractive power of the fourth eye-glass, made to enter the eye in parallel directions, and thus afford a view of the object nearly or wholly free from colour.

In forming the eye-glasses of telescopes it may be observed that they should be such as will allow the incident and emergent pencils of rays to be nearly equally inclined to their surfaces: on this account the first and fourth eye-glasses are of the plano-convex form; the flat side of that which is nearest to the object-glass being towards the latter, and that of the other towards the eye.

Besides the power of magnifying objects, that of affording distinct vision with given quantities of light is often an essential requisite in a telescope, particularly to naval men, who have occasion during the obscurity of the night to keep in view a ship of which they may be in chase. This subject was investigated by the late Sir William Herschel, and an account of his researches on what he calls the "space-penetrating power of telescopes" was printed in the 'Philosophical Transactions' for 1800.

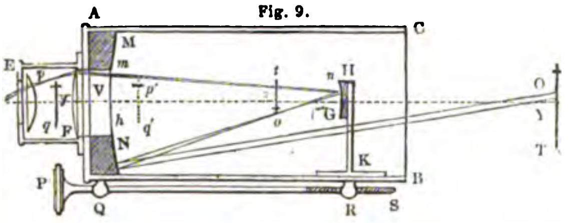
Herschel states that he was aware of this property of telescopes as early as the year 1777, when he had constructed a Newtonian telescope with a speculum whose focal length was 20 feet: for, on directing the instrument to a church-steeple at a considerable distance, he could distinguish the hour by the clock, though with the naked eye he could not see the steeple itself. In order to obtain a formula for the space-penetrating power, he observes that the quantity of light received by the natural eye varies directly with the aperture of the *pupil*, or with the square of its radius, and inversely with the square of the distance of the object: also that the quantity of light transmitted by a telescope, supposing none to be lost in the reflections from the mirrors, or in refraction through the lenses, will vary directly with the square of the radius of the aperture and inversely with the square of the distance of the object. But, from experiments on the measure of light, it appears that the whole quantity incident upon a plate of glass is to the quantity transmitted through it as 1 is to ·9381, or to the quantity lost as 1 is to ·0619; and from this, the whole quantity of incident light being unity, an estimate may be made of the quantity of light transmitted through all the lenses of a telescope: with respect to the quantity lost in reflection from mirrors Sir W. Herschel found that out of 100,000 incident rays, only 45,242 reached the eye after two reflections.

Let the quantity of incident light be to that which arrives at the eye as 1 to m; then r being the radius of the pupil, and R that of the aperture of a telescope, $\frac{R^2 m}{r^2}$ will express the ratio between the quantity of light transmitted to the naked eye, and through a dioptric telescope: therefore the space-penetrating power varying with the square root of the quantity of light, $\frac{R}{r}\sqrt{m}$ expresses the penetrating power. With respect to reflecting telescopes, if R' be the radius of the small speculum, the penetrating power will be expressed by $\frac{1}{r}\sqrt{\{m(R^2-R'^2)\}}$. It is necessary to observe that, in these expressions, it is supposed that the pencil of light transmitted by the telescope is not greater than the pupil of the eye.

It has been said above that, in reflecting telescopes, a speculum at one extremity of the tube serves the purpose of the object-glass in refracting telescopes by forming an image at its focus; and the manner in which, in the former instruments, the image is transmitted to the eye remains now to be explained.

The following diagram represents a longitudinal section through the axis X Y of the instrument, which is supposed to be of the Gregorian kind. A B is the tube which contains the specula, and is open at the end C B; and at the extremity nearest to the eye of the observer is a tube E F containing two lenses. M N is the anterior surface of the great speculum, which has a circular perforation, *mh*, at its centre: G is a small speculum, concave like the former, its surface being either spherical or parabolical. It is connected with the side of the tube A B by the arm H K, and is capable of being moved in the direction of the axis X Y by means of the rod P S: the latter passes through a knob Q, which is fixed to the side of the tube, and works in the knob R, which passes through an oblong perforation in the side of the tube, and is attached to the part K of the arm H K. This movement is given to the small mirror in order that its focus may be made to coincide with the place of the image formed by the great speculum; that image being at different distances from the latter according to the distance of the object from the observer.

Fig. 9.



Let O be the upper part of an object, and let O N be the direction of the rays in a pencil of light diverging from O; the rays of this pencil will, after being reflected at N, converge to *o*, which will be the lower part of the image *ot*. From *o* the rays in the pencil diverge, and having fallen upon the small mirror at *n*, they are reflected from thence towards the eye-piece E F: having passed through the orifice *mh*, they fall on the lens at F, by which they are made to unite at *p*, where an image, *pq*, of the object is formed. From *p* the rays in the same pencil again diverge, and, falling on the lens at E, they are made to emerge in parallel directions, so that the eye is enabled to obtain distinct vision of the object in the same position as if the latter were viewed by the naked eye. The rays, after being reflected at *n*, might with a due concavity of the smaller mirror have united, as at *p'*, in front of the great mirror, and the second image might have been formed at *p'q'*: in this case the rays in each pencil, after crossing one another, would have fallen in a divergent state on the lens at F, and then, by the refractive powers of both lenses, they would have entered the eye in parallel directions as before. The positions of the lenses at E and F, and the curvatures of their surfaces, are determined according to the method of Huyghens; and the construction differs in no respect from that which has been described in speaking of the eye-pieces of dioptric telescopes.

The magnifying power of a reflecting telescope of this kind is expressed by the formula $\frac{Vz \,.\, Gy}{Xy \,.\, Gz}$; in which Vz is the focal length of the great speculum, Gy is the distance of the small speculum from the image *pq*, Xy is the focal length of the second eye-glass, and Gz is the focal length of the small speculum for parallel rays.

In the Cassegrainian telescope the small mirror G is made convex, and it is placed so as to intercept the rays from the great speculum M N before the image *ot* is formed; the rays of each pencil consequently fall in a convergent state on the small mirror, and, after reflection from thence, unite to form the image either at *p'q'* or after refraction in the first eye-glass F. It is obvious that these telescopes, with equal magnifying power, will be shorter than the Gregorian telescopes by more than twice the focal length of the small speculum; and it may be added that, in some degree, the spherical aberration is corrected by the contrary curvatures of the two mirrors.

The Newtonian reflecting telescopes have one concave speculum at the bottom of the tube; and, in each pencil of light, the rays reflected from it fall in a convergent state upon a small plane mirror placed so as to make an angle of 45° with the axis X Y of the telescope: after the second reflection the rays unite and form an image which is viewed through a Huyghenian eye-piece fixed in the side of the tube A B, opposite the plane mirror; that is near the open end of the tube.

The great telescope constructed by Herschel differs from the Newtonian telescope only in having no small mirror. The surface of the great speculum, which is 4 feet in diameter, has a small obliquity to the axis X Y, so that the image formed by reflection from it falls near the lower side of the tube at its open end: at this place there is a sliding apparatus which carries a tube containing the eye-glasses. The observer in viewing, is situated at the open end of the tube, with his back to the object, and he looks directly towards the centre of the speculum, the magnitude of which is such that the rays intercepted by his head, in coming from the object, do not in any sensible degree diminish the brightness of the image.

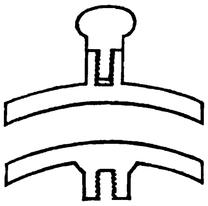
Formerly the great speculum of a reflecting telescope was pressed into its cell by means of springs attached to the interior side of the brass plate at A; but the vibrations of the springs were found to cause tremulous motions in the image at the focus of the mirror; and this effect was so great as to render reflecting telescopes inferior to those of the dioptric kind. The Rev. Mr. Edwards, who detected the cause of the tremors, at once removed it by taking away the springs ('Naut. Alm.,' 1787); and the same gentleman further improved the distinctness of the image by enlarging the aperture to which the eye is applied. It has been observed also that when the great speculum is nearly in a vertical position, and consequently rests on its lower extremity, its weight bends it, and thus causes a change in the figure of its polished surface: on this account it is recommended that the speculum should be made to rest on two small wedges, placed one on each side, at about 45° from the lowest point.

Since specula have been enlarged in their proportions the difficulties in the way of attaining distinct vision have increased. Sir W. Herschel's 48-inch reflector weighed 25 cwt., but the 6-feet speculum of Lord Rosse weighs no less than 4 tons. This, as Sir John Herschel remarks, requires the use of very powerful and costly machinery in the construction of such specula and also in their management when constructed. Speculum metal, though highly elastic and rigid is, as above noticed, liable to bend, and thus lose its figure. Herschel notices the case of a speculum of 18 inches aperture, 20 feet focus, and 2 inches in thickness which was found to be totally spoilt, by being supported on three points at its circumference, and when reclined against a flat and strong wooden back, with a single thin packthread interposed down the middle, all trace of figure was destroyed, and the surface was divided into two lobes, each producing an imperfect image of a star, connected with an irregular burr of light. Lord Rosse found that a strong pressure of the hand at the back of his 6-feet speculum, which is nearly 6 inches in thickness, produced sufficient flexure to distort the image of a star; and in one of Foucault's silver-glass mirrors the excess of central pressure of a somewhat over-inflated air cushion destroyed distinct vision. The speculum, therefore, requires to be uniformly supported over every part of the back. Where the weight does not exceed 200 or 300 lbs. a bed of several layers of even textured woollen blanket is sufficient, provided, as Herschel remarks "the whole be supported on a back so strong as not to yield under the pressure in any part more than a small aliquot of the total compression of the cushion." For small mirrors or for light glass ones an air-cushion is a good contrivance. For a very heavy one, such as Lord Rosse's six-feet speculum, an ingenious plan was adopted on the idea of the common "splinter bar," by which the pull of two, four, or eight horses drawing at once is equalised so as to distribute the work equally among them. The back of the mirror, supposed to be of uniform thickness, is divided into three sectors of 120°. Let the centre of gravity of each of these sectors be sustained by a projecting knob, at one of the angular points of a slab of iron in the form of an equilateral triangle, which is itself sustained by a point under its centre of gravity. In this way each sector being separately supported would produce no strain on the others, and the whole weight would be equally distributed among the three points of support. But to prevent the flexure of each sector it may be divided into three portions of equal weight, and the centre of gravity of each portion being found, it in turn is supported on a pin or knob on one angle of a smaller or secondary iron slab, which in its turn is supported on its centre of gravity by resting on one of the points of the primary triangle. In the case of a six-feet speculum each of these secondary areas may be subdivided into three equal tertiary areas similarly supported on tertiary triangular slabs each supported at its centre of gravity on one angle of a secondary one. In this way the mirror may be conceived as being subdivided into twenty-seven equal areas, each separately supported at its centre of gravity, and thus not liable to bend by its own weight. In practice, however, certain levers are introduced, the action of which does not interfere with the principle of the contrivance. This clever arrangement, however, was defeated by the adhesion or stickage, as it is called, of the metal to its cushion, and this stickage amounted to two tons when the speculum was resting on the bottom of the tube. Hence it has been found necessary to suspend the speculum from above, by means of bands of steel or some other support.

A reflecting telescope is liable to irregular action from currents of unequally heated air in the tube, which cause remarkable distortions and movements in the images of objects. Sir John Herschel ('Results of Cape Observations') describes a method of substituting for the tube an open frame-work of iron which gets rid of the objection from counter currents of air.

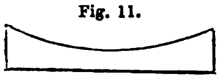
Under Speculum some details are given respecting the composition, the grinding, and the polishing of specula. As similar information respecting glass lenses is not given under the article Lens, the deficiency may to some extent be supplied in this place; the reader desirous of more ample information is referred to the third volume of Holtzapffel's 'Mechanical Manipulation,' 1850. The spherical surfaces of lenses are formed by grinding the glass in counterpart metal tools (*fig.* 10), prepared to the proper curvatures with the assistance of grinding and polishing powders. The tools are in pairs, concave and convex, and these are first made to correct each other's errors, which they do on the principle which applies also to the lenses themselves "of the natural tendency of two surfaces which grind each other by equable rubbing over every part to work each other into a spherical concavity and convexity exactly fitting." (Herschel.) Hence it is comparatively easy to form lenses into truly spherical surfaces.

Fig. 10.



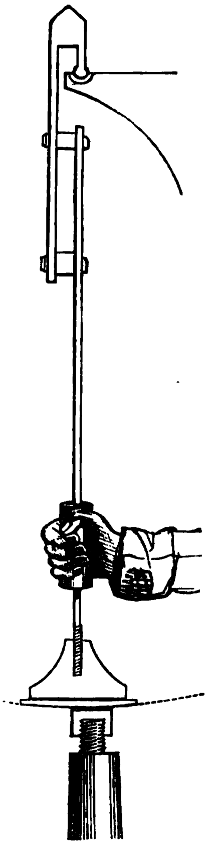
The concave and the convex tools grind each other true with the assistance of emery and water, although Mr. Ross thinks greater accuracy is attained by using the emery dry. The glass for the lens is brought to the circular form by means of *shanks* or flat pliers of soft iron, or to save the material (since good optical glass is more precious than gold) selected fragments of glass blocks are softened by heating to redness, moulded to nearly the required form, and then carefully annealed. Each lens is then coated on one side with a layer of cement, which is run into a hemispherical mass sufficiently thick to be grasped, so as to form a handle: but if the lens is of large size it is cemented to a metal handle, as a wooden one would swell. The cement is made by mixing wood-ashes with melted pitch. The glass is first rough ground within the metal shell or basin (*fig.* 11), either with river-sand and water, or coarse emery and water, until the surface is brought nearly to the curve of the shell. The glass is rubbed with large circular strokes, and when the grinding has been carried far enough, the glass is warmed, the cement handle is shifted to the other side, and the grinding is continued on the second surface of the lens. The parallelism of the two sides is obtained by observing that the edge of the glass is of equal thickness all round. The grinding is then continued with washed emery, six sizes being used, the last size being the fine powder collected after one hour's subsidence, and which leaves so smooth a surface that when the lens is held between the eye and the light it shows a semi-polish. Grinding the lens to the true figure or *trueing* the lens, as it is called, is generally done upon a post with the concave brass tool, much in the same manner as the concave and the convex brass tools are made to correct each other. The grinding is continued with each size of emery, until the marks made with the previous size are removed; everything being carefully washed between the changes of sizes; for should a speck of a larger size get into the work it might make a scratch which would render it necessary to re-commence the grinding. The polishing is performed with the assistance of putty powder, sifted through lawn and enclosed in a box with a lid perforated with small holes; or still better, mixed with water in a corked bottle, which is shaken up every time the powder is to be applied, and allowed to subside for a few seconds. A small quantity of the water is then taken out with a clean stick, and thrown upon the polisher, so that only the suspended portions of the putty powder are used. The powder is put upon a piece of thick silk (lute string), cut to the width of about seven-eighths the diameter of the lens, and stretched across the middle of the brass tool. The lens is rubbed backwards and forwards in straight lines along the silk, while at the same time it is twisted round in the hand, and also traversed gradually sideways, until the centre of the lens is brought to the edge of the silk, when the direction of the traverse is reversed. For the most carefully finished lenses, however, a pitch tool is prepared as described under Speculum.

Fig. 11.



Mr. C. Varley has described ('Trans. Society of Arts,' vol. xlix.) a lathe for grinding and polishing lenses in which instead of the lower tools being mounted on a fixed post they are mounted on a revolving axis placed vertically. Mr. Grubb, of Dublin, has an apparatus for figuring and polishing lenses, which is said to be very successful. For very accurate work, the arrangement shown in *fig.* 12 may be adopted. After grinding in the metal basin (*fig.* 11), the lens is attached to the lower end of a vertical rod, of which the upper end terminates in a steel ball, working in a cup and fitting accurately, so that every point of the surface of the lens may move in a spherical surface concentric with the steel ball. The rod is grasped by a woollen holder, to prevent the heat of the hand from elongating the rod. Below the lens is a small polisher of pitch, spread on brass and covered with a fine polishing powder mixed with water. The polisher admits of nice adjustment by means of a screw. The rod is worked to and fro as well as circularly, and the lens gradually acquires a perfectly spherical and polished surface, the radius of which can be adjusted by lengthening or shortening the rod. In manufactories where large quantities of common lenses are ground and polished, a number are arranged on a convex tool, such as 7, 13, or 21 around a central lens, forming what is called a *block* of lenses. Lenses of medium quality and size are generally ground true and polished seven at a time.

Fig. 12.



In forming the object glasses of achromatic telescopes, it is necessary to measure accurately the radii of curvature of the lenses, which are first tried experimentally, and are afterwards made as nearly as possible to the radii obtained by calculation. In order to measure the curvature of the grinding tools, Mr. Ross invented an instrument called a *spherometer*, a description of which will be found in the 'Trans. Society of Arts,' (vol. liii.)

The edges of lenses are made true by grinding in a lathe by means of a piece of brass supplied with emery and water; but in setting the lenses in the lathe for this purpose, it is cemented upon a chuck, and before the cement has set, the lathe is set spinning, and the reflection of a fixed object, such as a candle flame or a window bar is watched, and the lens is adjusted until the image appears to be quite stationary, notwithstanding the revolution of the lens. This shows that the axis of the lens and that of the mandril of the lathe coincide and consequently that the lens, when its edge is ground circular, and put in the tube of the instrument, will coincide with the axis of such tube.

The centering of the lenses of an achromatic telescope, so that all the centres of curvature of their surfaces shall lie in one straight line, and that coincide with the common axis of the telescope and its eye-piece, is an adjustment of considerable delicacy. Wollaston's method of doing this is described in the 'Philosophical Transactions' for 1822, and depends upon the circumstance that the various images of a candle, of which there are fifteen for a triple object glass, are, if the lenses be exactly centered, all in a right line directed from the candle.

TELESCOPE, HISTORY OF THE. It has been the fate of almost every instrument by which science has been extended, or the well-being of man promoted, that the precise epoch of its invention, and even the name of the individual to whom the world is indebted for it, are alike unknown. This is particularly the case with the telescope, of which the earliest notices are that it existed in England and in Holland near the end of the 16th or in the beginning of the 17th century.

There is in Strabo a passage (iii., p. 180, Falconer's ed.; p. 138, 'Casaub.') in which, speaking of the enlargement of the sun's disc at his rising and setting in the sea, it is stated that the rays (of light) in passing through the vapours which rise from the water, as through tubes, are dilated, and thus cause the apparent to be greater than the real magnitude (of the object); and from this it has been inferred (Dutens, 'Recherches,' &c.), though the inference is probably without foundation, that there then existed tubes furnished with lenses for magnifying objects by refracting the light. It would be needless to make any observations on an inference founded upon an hypothesis so obscurely expressed: the words in Strabo probably signify only that the rays of light might become divergent in passing along the intervals between the particles of vapour.

Omitting then all notice of this, and of the ill-understood passages in Aristophanes ('Clouds') and Pliny (lib. xxxvi., c. 67) concerning transparent spheres, or lenses for concentrating the rays of light, it must be acknowledged that before the end of the 13th century lenses of glass were in constant use for the purpose of assisting the eye in obtaining distinctness of vision. Vitello, a native of Poland, in that century, gave some obscure indications of the apparent magnitudes of objects when viewed through a segment of a sphere of glass; and Roger Bacon, in his 'Opus Majus,' both mentions the like fact, and expresses himself in such a manner as to indicate that in his time (he died in 1292) spectacles were already in use. He may not have actually made combinations of lenses in one instrument, but there is no doubt of his being aware of the fact that lenses might be arranged so that objects seen through them would appear to be magnified.

The idea being known to the learned, it is scarcely possible to doubt that the combination of two lenses, or of a concave or convex mirror and a lens, must have been often made during the three centuries which elapsed between the time of Bacon and that which is generally considered as the epoch of the invention of telescopes. Dr. Dee, in his preface to Euclid's 'Elements,' (1570) having mentioned that some skill is required to ascertain the numerical strength of an enemy's force when at a distance, observes that the "captain, or whosoever is careful to come near the truth herein, besides the judgment of his eye, the help of his geometrical instrument, ring, or staffe astronomical [probably for determining the measure of distances] may wonderfully help himself by *perspective glasses*." These last can only signify some kind of telescope, which therefore must have been then in general use. And in the 'Pantometria' of Digges (1571) it it stated that "by concave and convex mirrors of circular (spherical) and parabolic forms, or by frames of them placed at due angles, and using the aid of transparent glasses which may break, or unite, the images produced by the reflections of the mirrors, there may be represented a whole region: also any part of it may be augmented, so that a small object may be discerned as plainly as if it were close to the observer, though it may be as far distant as the eye can descrie." In the preface to the second edition (1591) the editor, who was the author's son, affirms that "by proportional mirrors placed at convenient angles, his father could discover things far off, that he could know a man at the distance of three miles, and could read the superscriptions on coins deposited in the open fields." There is probably some exaggeration in this account, but it is sufficiently manifest from it that reflecting telescopes, or optical instruments containing combinations of mirrors and lenses, were known in England before the end of the 16th century. The claim of Baptista Porta (between 1545 and 1615) to the invention of the telescope appears to have no other foundation than the circumstance that he perceived a small object to be magnified when viewed through a convex lens.

It is highly probable that the telescope had been invented long before the value of such an instrument was duly appreciated; and it may have been owing to the very gradual discovery of its importance that the name of the inventor sunk into oblivion: about the middle of the 17th century, however, an effort was made to discover the traces of the invention, and Peter Borellus, in his work entitled 'De vero Telescopii Inventore,' which was published in 1655 at the Hague, has given testimonials in favour of two persons; the first of these is Zachariah Jans, or Jansen, and the other, Hans Lapprey, or Lippersheim, both of whom are said to have been opticians, or spectacle-makers, residing at Middleburgh. In a letter written by a son of Jans, it is stated that the epoch of the discovery is the year 1590; but by another account, the year 1610. The same author has also given a letter from M. William Boreel (envoy from the States of Holland to the British Court) which seems to throw some light on the acts. The writer of the letter asserts that he was acquainted with the younger Zachariah Jans, when both of them were children, and had often heard that the elder was the inventor of the *microscope*: he adds that, about the year 1610, the two opticians Jans and Lapprey first constructed telescopes, and that they presented one to Prince Maurice of Nassau, who desired that the invention might be kept secret as (the United Provinces being then at war with France) he expected to obtain in the field, by means of the instrument, some advantages over the enemy. The writer further states that the invention became known, and that soon afterwards Adrian Metius and Cornelius Drebbel went to Middleburgh and purchased telescopes at the house of Jans. This account differs from that which is given by Descartes, ('Dioptrics,' cap. 1) who, writing in Holland, states that about thirty years previously, Metius (who was, he observes, a native of Alckmaer), having always taken pleasure in forming burning-mirrors and lenses of glass and of ice, by chance placed at the extremities of a tube two lenses, one thicker in the middle, and the other thinner, than about the edge (convex and concave); and thus, he adds, was formed the instrument which is called a telescope. The 'Dioptrics' was published at Leyden, in 1637, and therefore the time of the supposed invention by Metius is nearly coincident with that at which, according to Borellus, it was made by Jans. From the papers of Harriot, it appears that this mathematician observed spots on the sun, in 1610, with telescopes magnifying from ten to thirty times; but it is uncertain whether he got them from Holland, or whether they were made in this country; and the only conclusions at which it is possible now to arrive, are, that telescopes were known in England and Holland about the end of the 16th century, and that in both countries they were then in a form which rendered them practically useful.

The two Jansens, father and son, appear to have used their telescopes in observing the heavens; and the latter is said to have remarked four small stars near Jupiter: it has been concluded from thence, that he was the first discoverer of the satellites of that planet; but though this may be, he probably did not continue his observations long enough to enable him to determine their distances from it, or the times of their revolutions.

The use of the telescope, and, probably, even the knowledge of the fact that it had been invented, must have been for many years confined to the north of Europe; for it appears that it was not till the year 1609 that Galileo, who then happened to be at Venice, heard from a German a rumour of the discovery which was said to have been made in Holland. The Italian philosopher states, in the 'Sidereus Nuncius,' that he had then no knowledge of the nature of the instrument, and that he requested a friend at Paris to send him some information concerning it. On being informed, merely, that it was a tube containing glass lenses, his acquaintance with the nature of the refraction of light enabled him, it is said, to discover that one of the lenses must have been convex and the other concave, and also to determine the distance at which they should be placed from one another in order that the objects seen through them might appear magnified and distinct. Without however supposing that Galileo was here guided by theoretical considerations merely, it is easy to conceive that as lenses of different forms were then in use for spectacles, he might have obtained from an optician some which were of different degrees of convexity and concavity; and after a few trials he must have found such as would constitute an instrument possessing magnifying power.

The telescopes which he constructed consisted of one convex object-glass and one concave eye-glass, which were placed at the extremities of a leaden tube; and the first of them magnified the heights and breadths of objects three times only. Soon afterwards he made one which magnified eight times; and subsequently he succeeded in forming a telescope with a magnifying power which caused objects to appear about thirty times as great as they appear to the unassisted eye.

The knowledge which man had acquired of the visible heavens received many important accessions from the discoveries that Galileo was enabled to make by means of the telescope. Except the sun and moon, not one of the celestial bodies had hitherto been observed to have any visible form or magnitude, and it was to the eye of reason alone that those appeared to be anything but plane surfaces. The fixed stars and the planets were alike known only as luminous and ill-defined points; but when seen through a telescope, the planets were found to have certain magnitudes, and some of them to undergo variations of form; while the fixed stars appeared unchanged, or only divested of the radiance with which they seem to be surrounded when seen by the naked eye; and hence it became obvious that the former must constitute a distinct group of bodies infinitely nearer the earth than the others. The sun, from the spots observed on his surface, was found to revolve on its axis, and consequently was ascertained to be globular; and the light and dark spaces on the moon were distinctly perceived to be mountains and valleys, nearly resembling those features on the surface of the earth. Galileo relates, in the work above mentioned, that in the year 1610 he discovered the four satellites of Jupiter, and observed that they revolved about that planet as our moon revolves about the earth. Nearly at the same time he observed that Saturn presented a remarkable appearance: at first he thought it was accompanied by two smaller planets; but on using a telescope of superior magnifying power, these were found to be portions of a vast annulus which surrounds Saturn without touching his surface; and soon afterwards he ascertained the fact that Venus exhibited phases similar to those of the moon.

The species of telescope which was used by Galileo continued for several years unchanged; yet it is extremely defective, on account of the small extent of the field of view which it affords when its magnifying power is considerable; and the Batavian or Galilean telescope, as it was called, is now chiefly used in the form of an opera-glass. It is due to the memory of Kepler to state that he pointed out (in his 'Dioptrics') the possibility of forming telescopes with two lenses, both of which are convex; but he did not reduce his ideas to practice by the construction of such an instrument, and the honour of having been the first to do so is to be attributed to the Jesuit Scheiner, who, in his 'Rosa Ursina' (1650), gives a description of telescopes with one convex eye-glass. He observes that they cause the images of objects to appear in inverted positions; and adds, that thirteen years previously he had used such a telescope in the presence of the Archduke Maximilian.

Telescopes with a single convex eye-glass have been since designated *astronomical*, from the circumstance that they were long employed for celestial observations; the greater extent of their field of view having caused them, notwithstanding the inversion of the image, to supersede for that purpose the telescopes of Galileo. It ought to be remarked, however, that telescopes with two eye-glasses, by which the object might be seen in a direct position, as it appears to the naked eye, were described by Kepler, and constructed by Scheiner; but as they caused the object to appear much distorted and coloured about the margin of the field, they were not esteemed. Père de Rheita, about the same time, constructed for telescopes eye-tubes containing three lenses, which, he observes, afford a better image than those with two. The same person was the inventor of what is called a *binocular telescope*, that is, an instrument which consists of two telescopes having equal magnifying powers, and placed near each other in such positions that an object might be observed with both eyes at the same time. Attempts have been since made to revive this invention; but the advantages, if any there be, are more than compensated by the trouble of directing the two tubes to the object. By combining, however, the stereoscopic principle, some advantages are likely to arise, as in the case of the binocular microscope.

The magnifying power of a dioptrical telescope increasing with the ratio which the focal length of the object-glass bears to that of the eye-glass, and since, by increasing the focal length of the former without increasing its diameter, the coloured border round the image is diminished so that vision is rendered more distinct, the opticians of the 17th century were induced to form, for object-glasses, lenses which were segments of very great spheres—that is, lenses of great focal lengths. Campani, at Bologna, by order of Louis XIV., made telescopes having object-glasses whose focal lengths were as great as 136 feet; and with such, Cassini, in 1671, discovered the satellites of Saturn.

Huyghens, who was an ingenious mechanic, as well as a good philosopher, contrived to use an object-glass of long focus for astronomical purposes without placing the system of lenses in a tube. On the top of a long pole which was planted vertically in the ground, he mounted the object-glass, having fixed it in a frame with joints so that its axis could be moved in any direction by means of a string which was held in the hand of the observer; and the axis being in a line passing through the celestial body, a short tube containing the eye-glasses was fixed to a stand near the ground with its axis in the same direction. An *aërial refractor* (as this kind of instrument was called), having an object-glass 123 feet focal length, was made by Huyghens and presented to the Royal Society; and with it Dr. Bradley made some of his astronomical observations. Pound used it to furnish the diameters of Jupiter and Saturn, and the elongations of their satellites, calculated on by Newton in his 'Principia.' It is described by Huyghens in his 'Astroscopia Compendiaria,' which was printed at the Hague in 1684. M. Auzout is said to have executed an aërial refractor at Paris of 600 feet focal length; but this proved unmanageable. But the chief merit of Huyghens as an improver of astronomical telescopes consists in his construction of an eye-piece with two lenses so combined as both to enlarge the field of view and diminish the aberrations produced by their spherical forms.

There is some probability that the elder Digges had contrived an instrument which constituted a species of catoptric or reflecting telescope; but, on account of the obscure manner in which the instrument is described, it will be scarcely necessary to notice further his claim to the honour of the invention. It appears that Père Mersenne, in his correspondence with Descartes, and in his 'Catoptrics' (1651), suggested the idea of a concave spherical mirror to be used, like the principal lens of a dioptric telescope, for forming in its focus an image of an object; and that this image being viewed through a convex eye-glass of proper curvature, the original object would appear to be magnified. Descartes, in his reply to Mersenne, which is said to have been written in 1639, makes several objections to the scheme, and no effort was then made to put it in practice. But the great length of the dioptric telescopes which were then in use rendering the management of them very inconvenient, ingenious men were induced to attempt a construction in which, with equal magnifying power, much smaller dimensions might be employed. Mr. James Gregory of Edinburgh, in his 'Optica Promota' (1663), published a suggestion for forming a telescope by means of the image at the focus of a concave speculum. The mirror was to be of polished metal with a paraboloidal surface, which by the properties of that curve would cause all rays incident upon it in directions parallel to the axis to converge accurately at one point. It is uncertain whether Gregory had any knowledge of Mersenne's treatise, or whether the idea originated with himself; but this is of little consequence, for not being able to find an artist who could execute such a speculum, though he came to London for the purpose, the suggestion was abandoned, and men of science continued to direct their inquiries to the means of improving dioptric telescopes.

When, however, Newton had discovered the unequal refrangibility of light, and had ascertained that the aberration produced by this cause about the focus of a lens was many hundred times greater than that which was caused by the spherical form of the glass, he gave up the hope of being able to construct refracting telescopes which should be free from this defect, and applied himself to the formation of specula for those of the catoptric kind: the image formed by reflection from a mirror being free from what is called the *chromatic aberration*, and consequently incomparably more distinct than one which is formed by the refraction of light in a lens of any transparent medium.

In the beginning of 1669, Newton having obtained a composition of metals which appeared likely to serve for a mirror, began with his own hands to grind its surface to a spherical form; and early in the year 1672 he completed two telescopes: of the construction and performance of these instruments he sent to the Royal Society an account which was read in the January of that year. The radius of the concave metal in one of them was 13 inches, and the telescope magnified about 38 times. The rays, before forming an image in the focus of the speculum, were intercepted by a glass prism, or a plane mirror, and the image formed after this second reflection was viewed by a convex eye-glass which was fixed for the purpose in the side of the tube. In the telescope proposed by Gregory, the rays in each pencil of light, after crossing at the focus of the great speculum, were to fall upon the surface of a small concave mirror; and by this being again reflected, they were to form a second image near the anterior surface of the first speculum: through a perforation in the latter the image was to be viewed; a convex lens being interposed between the image and the eye of the observer. This has been always called the Gregorian telescope; and in 1672, the year in which Newton completed his reflecting telescopes, M. Cassegrain, in France, proposed one which differed from that of Gregory only in the rays reflected from the great speculum being intercepted by a small convex mirror; from this the rays of each pencil were again reflected, and they were made to form an image near the anterior surface of the great speculum; this image was to be viewed through a convex lens behind an aperture in the latter speculum, as in the telescope of Gregory. It does not appear that M. Cassegrain constructed such a telescope, but it may be observed that the image formed after reflection from the convex speculum would be more free from the aberration caused by the surfaces of the mirrors, and would also be rather greater, than that which is obtained from the concave speculum of Gregory, or the plane one which was used by Newton.

The first reflecting telescope, in which the great speculum was perforated so that objects could be viewed by looking directly at them, was executed by Dr. Hooke, and produced before the Royal Society in February, 1674. But the difficulty of obtaining metal proper for the purpose, and of giving it a perfectly spherical form, for a long time prevented reflecting telescopes from attaining the desired degree of perfection. In 1718 Mr. Hadley succeeded in executing two telescopes, each about five feet long, which were considered good; and he gave, in the 'Philosophical Transactions' (1723), a description of the methods employed in their construction. By his advice Dr. Bradley, who was then professor of astronomy at Oxford, in conjunction with Mr. Molyneux at Kew, applied themselves to the construction of these instruments: having executed one which was satisfactory, they in 1738 instructed Scarlet and Hearne, two London opticians, in the processes which they used, and these artists presently succeeded in making good reflecting telescopes for general sale. Mr. James Short of Edinburgh, also soon afterwards distinguished himself by his skill in forming such telescopes: he attempted at first to make the principal speculum of glass, but finding that this material had not sufficient steadiness to preserve the form of its surface, he devoted himself to the improvement of metallic specula, and succeeded in giving them, it is supposed, a correct parabolic figure, by which means his telescopes admitted of larger apertures than any that had before been made.

The processes adopted by Mr. Mudge in grinding and polishing the mirrors for reflecting telescopes, and in giving them the parabolic figure, may be seen in the 'Philosophical Transactions' for 1777. See also SPECULUM.

But the reflecting telescope was carried to a high degree of excellence by Dr. (afterwards Sir William) Herschel. This distinguished astronomer, while residing at Bath, employed his leisure hours in grinding and polishing specula, with which he formed telescopes, both of the Newtonian and Gregorian kinds; and about the end of 1783, that is subsequently to the discovery of the planet which is sometimes called by his name, being aided by the liberality of the king (George III.), he began the formation of a speculum four feet in diameter and forty feet in focal length: the telescope to which it appertains is of the Newtonian kind, the observer being placed in a seat near the open end of the tube, and viewing the image through a system of eye-glasses. With this telescope, which was completed in 1789, objects are magnified about 6500 times; and on the night after it was finished, Dr. Herschel discovered the sixth satellite of Saturn. The attempts that have been made to form a reflecting telescope possessing a higher degree of perfection than that of Herschel will be noticed presently.

While the improvement of reflecting telescopes was in progress, the efforts to combine glass lenses in order to diminish the coloured fringes by which the images in dioptrical telescopes are surrounded were not entirely neglected; and as early as 1729, a private gentleman, Mr. Chester More Hall, of Essex, influenced, it appears, by an opinion that the humours of the eye are combined so as to correct the dispersions which each alone would produce in the different kinds of light, contrived to 'combine two lenses of different kinds of glass in such a way as to form an image which was free from colours: it is added that telescopes with such object-glasses were in the possession of several individuals many years afterwards. ('Gent. Mag.', October, 1790; 'Phil. Mag.', November, 1798.)

In 1747, Euler, guided also by the constitution of the eye, conceived the possibility of forming a lens compounded of two hollow spherical segments of glass, inclosing water between their concave sides, which should be free from the chromatical and spherical aberrations; and in investigating the curvatures, he assumed that the logarithms of the terms expressing the ratio of the refraction of a mean ray in passing from air into glass, and from air into water, were proportional to the logarithms of the terms expressing the ratio of the refractions of red rays in the same media. He was not able to obtain from any artist a lens of this nature, in which the proposed end was accomplished, and Mr. Dollond, in a short paper which is printed in the 'Philosophical Transactions' (1752), contested the justness of Euler's principle on the ground that it was contrary to one which he conceived to be founded on the experiments of Newton.

But M. Klingenstierna, a Swedish mathematician, having soon afterwards, in a Mémoire which was sent to the Académie des Sciences, pointed out that the principle which had been adopted by Dollond was not conformable to the acknowledged laws of refraction, the latter determined immediately on having recourse to experiment. Either guided by the object-glasses constructed under the direction of Mr. Hall, or from a series of experiments made by himself on the refraction of light in wedges of crown and flint glass, he discovered that by employing a convex lens of the former, in combination with a concave lens of the latter kind, the rays of the different colours in each pencil of light, after refraction through both, might be made to unite at the focus, and thus produce an image of the object nearly free from colour. For this important discovery Mr. Dollond received from the Royal Society the Copleian medal. In 1765 his son, Mr. Peter Dollond, diminished the aberration of light on account of the spherical forms of the lenses by combining together two convex lenses of crown glass with a concave lens of flint glass between them: this construction is particularly advantageous, by the increased aperture which it allows when the focal length of the compound lens is short.

For several years after the telescopes thus improved by Dollond had been in general use, Euler continued to believe that all kinds of glass differed but little from each other with respect to their dispersive power, and he ascribed the success of the English artist merely to a fortunate determination of the curvature of his lenses; but having, in the year 1764, received information that, by the addition of lead, glass had been obtained whose dispersive power was four times as great as that of the common kind, he immediately renounced his former opinion; and from that time the merit of the achromatic object-glasses, as they were called, has been firmly established. The most eminent mathematicians, both on the Continent and in this country, have subsequently investigated, on scientific principles, the curvatures which should be given to the surfaces of lenses, so that, the focal length of the compound lens being assumed, the chromatical and spherical aberrations may be corrected.

The arrangement of lenses for the eye-pieces of telescopes is of no less importance than the formation of the object-glass; and Huyghens proposed ('Dioptrica,' prop. 51), in order to diminish the refraction of light at the surfaces, to substitute for the single eye-glass of the common astronomical telescope two convex lenses, of such curvatures that the whole refraction, or the angle between the incident and emergent ray in the former construction, should be divided between the two lenses.

One mode of effecting this purpose is to place the first eye-glass, or that which is nearest to the object, so as to intercept the pencils coming from the object-glass before the rays are united, and thus the image is formed after the refraction of the light in this lens: the second eye-glass is then placed so that the rays falling on it, after having crossed at the place of the image, are made to enter the eye parallel to one another. A micrometer cannot be applied to such an eye-piece, since any change in the place of the lens which is nearest to the eye would derange its adjustment: these eye-pieces can however be rendered achromatic, and they have the greatest possible field of view; they have therefore been constructed for the purpose of merely viewing the celestial bodies by Dollond, Ramsden, and Frauenhofer. Mr. Ramsden was the first who constructed eye-pieces with two lenses which were capable of being used with a micrometer: this he accomplished by placing the tube containing those lenses so that the rays in the pencils, after crossing at the focus of the object-glass, fell in a diverging state upon the first eye-glass, and, after refraction in both, entered the eye in parallel directions.

With both these kinds of eye-pieces the object appears to be inverted; but eye-pieces with three lenses, by which the object is made to appear in the erect position, had been proposed by Rheita: these being found defective, Mr. Dollond endeavoured to improve upon the construction by dividing the refraction at the first and third eye-glasses between two lenses, according to the method recommended by Huyghens; and thus he formed eye-tubes with five lenses. But some light is always lost by reflection when it falls upon glass; and in order to diminish this evil, Dollond subsequently, retaining the Huyghenian construction in the two lenses nearest to the eye, used but one lens to perform the office of the second and third (in the eye-piece with five glasses), in rendering the rays of each pencil convergent after the first had diminished the divergency caused by the crossing at the focus of the object-glass: he thus succeeded in producing an eye-piece of four lenses which was nearly *aplanatic*, or free both from the chromatical and spherical aberrations; and such are the telescopes now in common use for viewing terrestrial objects.

The chief improvements, if they may be so called, which have since been made in dioptric telescopes, consist in the means which have been adopted to remove those aberrations more completely; and the nature of the different media which have been used for this purpose by Dr. Blair, Sir David Brewster, and Mr. Barlow, are mentioned under TELESCOPE.

We must, however, briefly notice the attempts that have been made of late years to improve what is called *optical* glass. Flint glass is subject to numerous defects resulting from a want of uniform density, which defects are so common as to have obtained distinguishing names, such as *striæ*, or *wreath*, *knots*, *threads*, and *tears*. The striæ are undulating appearances in the glass, whereby the light in passing through it is refracted and dispersed in different directions, producing a wavy effect not always apparent until the glass enters into the construction of an optical instrument. Knots are opaque particles derived from the glass-pot, or particles of glass-gall, or imperfectly vitrified grains of sand. Threads and tears also consist of partially vitrified matter. The glass may also want clearness from the presence of minute bubbles or seed, as it is called, diffused through the glass in consequence of its not having been kept sufficiently fluid. It is said that good results have been obtained by horizontal sections of the whole contents of a pot of glass.

Our space will not allow us to do more than indicate the various attempts that have been made to improve optical glass. After the discovery of the achromatic principle, it was seen how important it was to obtain glass of uniform density. Dollond, and the best opticians abroad, had extreme difficulty in obtaining glass adapted to their purpose. The Academy of Sciences at Paris offered prizes in vain for unobjectionable optical glass: some of the best chemists devoted their attention to the subject, but they did not succeed in obtaining larger glasses than from 3 to 3½ inches in diameter. Manufacturers also made the attempt without success. M. Guinand, a watch-maker of Brenets, near Neufchâtel, in Switzerland, was the first to approach the solution of the difficulty. He is said to have got rid of striæ by diligently stirring and mixing the materials while in a state of fusion. His success was such as to induce M. Utzschneider, of Munich, to join him and M. Frauenhoffer in their establishment at Benedictbaüern in Bavaria. He accepted the offer, and remained with them from 1805 to 1814; one of the largest glasses resulting from their experiments (9 inches in diameter) is now in the Observatory at Dorpat. Guinand's presence greatly improved this manufactory, and achromatics of 6, 7, 8, and 9 inches in aperture issued from the establishment, which continued after the death of Frauenhofer to maintain its reputation under the management of Messrs. Merz and Mahler. Guinand, towards the close of his life, had some communication with the Astronomical Society of London. A disc of flint glass, 6 inches in diameter, was reported on favourably by Messrs. Dollond, Herschel, and Pearson. A commission was also appointed, consisting of Messrs. Herschel, Faraday, Dollond, and Roget, to inquire into the manufacture of flint glass. Mr. Faraday pursued the inquiry for some time, and succeeded in producing a borate of lead of remarkable purity. But the excise officers were found to be so obstructive in their regulations, as to make it very difficult to pursue the inquiry, which was, therefore, terminated. Guinand is said to have imparted his secret to his sons before he died, and they endeavoured to sell it on the best terms in England and France. M. Bontemps became associated with one of the sons, and in 1828 they succeeded in producing good flint glass, the largest discs being from 12 to 14 inches. Guinand's widow and another son established works in Switzerland, and were succeeded by M. Daguet, of Soleure, some of whose products appeared at the Great Exhibition of 1851. The Jury Report, Class XXIV., states that these discs "confirm the belief that there are even more impediments in fabricating crown glass of large size, than in making good crystal. In order to render it free from impurity, it becomes more difficult of manufacture, more liable to tension, and to accidents. It requires a higher temperature. By increasing the facility of fusion, the disposition to attract humidity, or to sweat, is increased. In rendering it too hard, the risk of crystallisation and imperfect vitrification in cooling, is incurred."

Soon after 1848, M. Bontemps joined the house of Messrs. Chance, Brothers, and Co., who determined to devote some of their large means to the manufacture of optical glass. They succeeded in producing discs of extraordinary dimensions—in flint of 29 inches in diameter, weighing 2 cwt., and of crown glass up to 20 inches. The large flint glass was ground and finished, and was said to be so uniform in density and otherwise satisfactory, that the Jury recommended a council medal to be awarded to the manufacturers.

Mr. Ross has called attention to a defect in optical glass, which may be detected by the searching agency of polarised light. A glass of not more than 6 inches in diameter, undergoes the annealing process with difficulty, cooling more rapidly at the surface than in the interior, and as this tendency increases with the size, the production of a disc of 29 inches is justly regarded as a very remarkable work.

Sir John Herschel, in a recent article on the telescope ('Ency. Brit.') suggests that the ultimate perfection of the achromatic telescope would be obtained were it possible to manufacture other species of glass with a much lower dispersive power than crown or plate glass, or a different action on the rays of intermediate refrangibility. The fluoric compounds have remarkably low dispersive power, that of cryolite and fluate of lime is only two-thirds that of plate glass, holding nearly the same place with respect to this glass that the latter does to flint. The fluoride of strontium is also suggested as a promising material. It is also stated that M. Jamin, by using oxide of zinc instead of that of lead in flint glass, has succeeded in forming a zinc flint glass of exquisite limpidity, of low refractive and dispersive power, and capable of being wrought into discs of any size.

Attempts have been made by M. Chevalier to diminish the aberrations by means of two achromatic object-glasses placed at a certain distance from each other in the tube; and by Mr. Rogers of Leith, by a single convex lens of plate-glass, in combination with a double achromatic lens, the convex lens being of plate-glass, and the concave lens of flint-glass. This last gentleman proposes to unite the red and violet rays at the image of the object by a proper distance between the single and the double lens, and to correct the spherical aberration either by giving proper curvatures to the surfaces of the compound lens, or by placing the two lenses at a small distance from each other in the narrower part of the converging cone of rays. ('Memoirs of the Astron. Soc.,' vol. iii.)

This was reduced to practice in 1839 by M. Plössl, of Vienna, under the name of the Dialytic Telescope, which is characterised by Sir John Herschel as "a very artificial and beautiful invention, highly deserving further trial." Somewhat resembling this contrivance is Mr. Peter Barlow's plan of placing in the narrowing cone of rays from a plate-glass object-lens a concave lens formed of two plate-glass capsules of equal thickness, inclosing between them a highly dispersive fluid, namely, the bisulphide of carbon, of which the refractive index is 1·678, and the dispersive power 0·115, or more than double that of flint-glass. This fluid lens is concavo-convex. By proper curves the spherical aberration can be destroyed; and by varying the distance between the two lenses, exact achromaticity can be produced. The principle was tested in a telescope of 8 inches aperture and 12 feet focal length, with success: as Mr. Barlow remarks, "less than an ounce of sulphuret of carbon, value three shillings," was made to perform the office of a very costly flint disc of 8 inches. ('Phil. Trans.,' 1828, 1829, 1831.)

Sir D. Brewster has suggested ('Treatise on New Phil. Inst.,' p. 400) that it may be possible to remove, or at least very much diminish, the uncorrected colour in the image by the use of two lenses of the same kind of glass with the same or different dispersive powers. He proposes that the exterior lens should have the meniscus form, the convex side being outwards, in order, from the obliquity of the incident rays to the surface, that the dispersion produced by that lens may increase in a higher ratio than its refraction, so that the dispersion produced by the other lens may be corrected; while in each pencil the rays, after refraction through both, may be convergent.

It would be improper to omit here to mention that M. Amici, at Modena, some years since, invented a species of achromatic telescope by a combination of four prisms, all of the same kind of glass: the refracting edges of one pair of the prisms were parallel to one another, and those of the other pair were also parallel to one another, but perpendicular to the edges of the first pair; and each pair formed an achromatic combination. By the refraction in the first pair, the breadth of the object is magnified, and by that in the second pair the length is magnified in the same ratio: thus the result is an image undistorted and magnified. Sir John Herschel states that, in 1826, he saw in the hands of its inventor one of these telescopes, which magnified about four times.

The success which Sir W. Herschel obtained in the construction of reflecting telescopes was unrivalled during many years; but at length has been surpassed by Earl Rosse, who has erected in the grounds of Birr Castle, Parsonstown, Ireland, two telescopes, in the lesser of which the speculum is of three feet aperture, and in the greater telescope 6 feet, or a reflecting surface of 28·274 square feet, being greater than that of Herschel's large telescope in the ratio of 7 to 3. Its focal length is 53 feet. It can be used either on the Newtonian or the Herschelian principle. The great tube is of wood hooped with iron, and is 7 feet in diameter and 52 feet in length. It is suspended between two lofty meridional walls of solid masonry, between which its upper end is allowed a considerable amount of lateral motion, so as to admit of taking up the view of a celestial object some time before its arrival on the meridian, and following it for some time after, without displacing the lower end. This lower end is supported on a massive universal joint of cast iron, resting on a stone pier buried in the ground, and so counterpoised as to be easily moved in declination. The preparation of the speculum, which weighs 4 tons, is described under Speculum. The stairs and galleries for the observers are supported by the western pier. The first gallery commands a view of objects at an altitude of 42°. It consists of a strong light prismatic framing sliding between two fixed ladders; it is counterpoised, and can be raised to the required position by means of a windlass. There are three other galleries at the summit of the western pier, which command the heavens to five degrees below the pole. Each gallery is supported by beams which run between grooved wheels. For some of the achievements of this splendid instrument we may refer to a Memoir by Lord Rosse, 'Phil. Trans.' 1850. See also Nebulæ.

Mr. Lassells' reflector has a clear diameter of 2 feet, and 20 feet focal length; it was originally erected at his residence near Liverpool, and in 1852 was removed to Malta, for the advantage of a clearer atmosphere and a lower latitude. By means of this instrument, Mr. Lassells discovered two of the satellites of Uranus, one of Saturn, and one of Neptune. This instrument is erected under a revolving cupola 30 feet in diameter, carrying a stage for the observer. The image may be deflected towards the eye-glass, either by a small two-inch speculum, or by a prism. To prevent dew forming on the latter, a small piece of heated lead is placed in a case near it. Metal does not contract dew, but glass is peculiarly liable to deposit it; hence achromatics are generally furnished with a dew-tube, which is merely a brass cylinder blackened within.

In Mr. Nasmyth's reflector, the rays from the great speculum are received on a small speculum or prism, placed in the axis of the tube, between the focus and the great speculum, by which they are reflected at right angles, and the image is formed in a tube inserted in one of the trunnions, on which the instrument turns. The image is then viewed in the usual way by an eye-piece; the advantage is, that while the great tube is moved in altitude, the side-tube is fixed, and the observer can survey the whole meridian or any other vertical circle without changing his position. The instrument is moved in azimuth by means of a turn-table, on which is the frame of the instrument and the seat for the observer, who can thus command every required motion, both in altitude and azimuth. The great tube has a length of 28 feet, and a diameter of 54 inches.

Telescopes for general astronomical purposes are now almost always mounted equatorially, and great improvements have been made in the mounting, the method of the Astronomer Royal being particularly recommended for its lightness, combined with extreme stiffness to resist both flexure and twist.

The history of the telescope may be assisted by reference to the following heads: Equatorial; Transit; Speculum; Achromatic; Light; Lens; Aplanatic Lens; Aberration; Micrometer; Eye-piece; Astrolabe; Quadrant; Theodolite; Heliostat; Heliometer; Optometer; Refraction; Dispersion.

TELESCO'PIUM (the Telescope), a constellation of Lacaille, in the southern hemisphere, surrounded by Ara, Pavo, Sagittarius, and Ophiuchus. Its principal star is as follows:—

Character.	No. in Catalogue of Piazzi.	No. in Catalogue of British Association.	Magnitude.
α	50	6240	4

TELLER-BISMUTH. [Tellurium.]

TELLERS OF THE EXCHEQUER (*tailler*) were the holders of an ancient office in the Exchequer. [Tally.] They were four in number; their duties were to receive money payable into the Exchequer on behalf of the king, to give the clerk of the pells (skins or rolls of parchment) a bill of receipt for the money, to pay all money according to the warrant of the auditor of receipts, and to make weekly and yearly books of receipts and payments for the lord treasurer. (4 'Inst.', 108; 'Com. Dig.', tit. 'Court,' D. 4, 14, 15.) The office was abolished by act of parliament (4 & 5 Wm. IV., c. 15), together with that of the clerk of the pells and the several offices subordinate thereto.

TELLURETTED HYDROGEN. [Tellurium.]

TELLURIC ACID. [Tellurium.]

TELLURIUM (Te) is a rare element, very similar to Selenium, and closely allied to Sulphur. It is sometimes found in the free state, but usually occurs in combination with metals forming *tellurides*. [Tellurium, in Nat. Hist. Div.] From the Nagyag ore, which contains about thirteen per cent., it is obtained by dissolving in nitric acid after the sulphides of lead and antimony have been separated by digestion in hydrochloric acid. The nitric acid solution is evaporated to dryness, the residue treated with hydrochloric acid and filtered, and tellurium thrown down from the filtrate by the addition of sulphite of soda.

Tellurium has a silver-white lustre, and is very brilliant: it is crystalline and brittle, of a lamellar fracture, easily pulverised, and a worse conductor of electricity than antimony or bismuth. Its specific gravity is 6·65. It is nearly as fusible as antimony, and at a high temperature it boils, and may be distilled. When strongly heated in contact with air, it burns with a lively blue flame, green at the borders, and forms a white vapour, which has an acid odour.

The equivalent of tellurium is 64·5.

Tellurium and *oxygen* form two compounds:—

Tellurous acid	TeO_2
Telluric acid	TeO_3

Their constitution is obviously similar to that of sulphurous and sulphuric acids.

TELLURIUM-AMYL. [Organo-Metallic Bodies.]

TELLURIUM-ETHYL. [Organo-Metallic Bodies.]

TELLURIUM-METHYL. [Organo-Metallic Bodies.]

TELLUROUS ACID (TeO_2). It has been already mentioned that when tellurium is heated in contact with air, it burns, and a white vapour is formed: this is oxide of tellurium, or tellurous acid. It may also be obtained by the action of nitric acid on the metal; by adding water to the solution, part of the oxide is precipitated, and the remainder is obtained by evaporation to dryness. It is a white granular anhydrous powder, which slowly reddens moist litmus-paper, and is insoluble in water and acids. It is dissolved by a solution of potash or soda, and by fusing with their carbonates crystallisable salts are formed: when these are decomposed by acids, hydrated tellurous acid is precipitated, which, if washed with very cold water and dried at a temperature not above 53° Fahr., may be preserved without suffering change. The hydrate is soluble in water, acids, ammonia, and the alkaline carbonates, which last it decomposes: the aqueous solution reddens litmus-paper: when zinc, tin, and some other metals are left in a solution of this acid, they deoxidise it, and metallic tellurium is precipitated in the state of a black powder. Its salts are called *tellurites*.

Telluric Acid (TeO_3).—This compound is obtained by fusing tellurous acid with nitrate of potash, which oxidises it completely, and the result is tellurate of potash. When chloride of barium is added to the last-named salt, tellurate of baryta is precipitated, which being decomposed by sulphuric acid, yields a solution of telluric acid, and this solution furnishes hexagonal crystals of the acid. It acts but feebly as an acid, the dilute solution reddening litmus-paper with difficulty, and its taste is rather metallic than sour: the crystals contain water, two-thirds of which they lose at about 212°; the remainder below a red heat becoming a mass of a fine orange colour, which is completely insoluble in water, either cold or boiling, or hot hydrochloric or nitric acids, or solution of potash. It is decomposed at a high temperature, and converted into a white powder, which is tellurous acid. Its salts are called *tellurates*.

Hydrogen and Tellurium form *telluretted hydrogen* (TeH).—When tellurium is alloyed by fusion with tin or zinc, and the compound is acted upon by hydrochloric acid, the hydrogen of the decomposed acid dissolves tellurium, and telluretted hydrogen gas is obtained. This gas has a smell resembling that of hydrosulphuric acid: it is soluble in water, forming a colourless solution, which becomes brown by exposure owing to separation of tellurium. As it possesses acid properties, though to a slight extent only, it has been called *hydrotelluric acid*. It decomposes many metallic salts, yielding an alloy of tellurium with the other metal. Chlorine, nitric acid, and the oxygen of the air, all take the hydrogen from the tellurium.

Chlorine and Tellurium form two compounds. When a feeble current of chlorine gas is passed over tellurium at a high temperature, the *chloride* formed passes over as a violet-coloured vapour, which condenses at first into a black liquid, and eventually into a solid of the same colour. It is decomposed by the action of water into metallic tellurium, which is precipitated, and bichloride of tellurium, which remains in solution.

It is composed of one equivalent of chlorine, and one equivalent of tellurium (TeCl).

The *Bichloride of Tellurium* ($TeCl_2$) is obtained, as above stated, by the action of water on the bichloride, but is better procured by passing a larger quantity of chlorine over tellurium at a lower temperature than in forming the chloride. It is volatile, and any excess of chlorine being separated by agitation with mercury and rectification, it is obtained as a white crystalline solid.

Sulphur and Tellurium combine in two proportions: the *bisulphide* (TeS_2) is obtained when hydrosulphuric acid gas is passed through a solution of tellurous acid, or of a soluble tellurite. It is of a dark brown colour, and is soluble in a solution of potash.

Tersulphide of Tellurium (TeS_3) is obtained by mixing a solution of persulphide of potassium with one of a salt of telluric acid. It is of a deep yellow colour; but it is a very unstable compound, for it speedily becomes black, and is converted into bisulphide.

TEMPERA (Ital. *à tempera*), that method of painting in which the vehicle employed is composed of a glutinous material (usually glue, white of egg, or gum), diluted (or "tempered") with water; gesso, or plaster of Paris, being added to the colours to give them greater consistency, or, as it is termed, body. This was the method employed by the ancient Egyptians, the Greeks prior to the introduction of wax as a vehicle [Encaustic Painting], and by the early Christian painters. [Painting.] Distemper-painting, as now practised by scene-painters and decorators, is only a less refined form of tempera, from which it has indeed derived its designation. [Distemper; Scene-Painting.]

TEMPERAMENT (*temperamentum, κρᾶσις*) is a vague and unsatisfactory term, but it is one which as Mayo observes ('Pathology of the Human Mind') has been long and generally adopted as a convenient generalisation. The word means literally *a tempering*, or *mixing together*, and may be defined to be a peculiar state of the system common to several individuals, which results from the various proportions in which the elementary parts of the human body are *mixed up together*, and which gives rise to a tendency to certain phenomena. There is, besides, in each individual a further peculiarity of combination, which serves to distinguish his temperament from that of any other person, to whom, however, he may in other respects bear a great resemblance. This individual temperament is called an *idiosyncrasy* (that is, a peculiar mixing together), and, as the two words are sometimes confounded, it may be useful to point out the distinction between them. All the different systems of organs in the human frame are accurately adjusted to each other, so as to produce one harmonious whole. If the disproportion be too great, disease ensues; but there are many gradations, compatible with health, where yet this disproportion is very observable. The predominance of any particular system of organs modifies the whole economy, impresses striking differences on the results of the organisation, and has perhaps almost as great an influence on the moral and intellectual as on the physical faculties. This predominance establishes the temperament: it is the cause of it, and constitutes its essence. The ancients paid considerable attention to the subject of temperaments, and pointed out various peculiarities in the constitution and actions of the human body, which have been seen so far to coincide with general observation, that their nomenclature has continued in very general use even to the present day, although the hypothesis on which it was founded is universally discarded. They described four temperaments corresponding to the four qualities of Hippocrates—hot, cold, moist, and dry. It was supposed that there were four corresponding primary components of the human body, namely, blood (*αἷμα*), phlegm or pituita (*φλέγμα*), and the two kinds of bile (*αἱ δύο χολαί*), yellow bile (*ξανθὴ χολή*), and black bile, or atrabilis (*μέλαινα χολή*); and the preponderance of one or other of these components in different persons produced the different temperaments. These four primary principles of living bodies were supposed to be compounded of the simple elements or qualities of nature thus: hot and moist produce blood; cold and moist, phlegm or pituita; hot and dry, yellow bile; and cold and dry, black bile. Bodies in which blood superabounds are of the sanguine temperament; if phlegm is in excess, the phlegmatic temperament is developed; if yellow bile, the choleric; and if black bile, the melancholic or atrabilious temperament. A minute description of the different temperaments is given by Paulus Ægineta, 'De Re Medica,' lib. i. cap. 61. The due admixture of the different qualities was supposed to constitute the best form of temperament or constitution (*εὐκρασία*), of which the following is Paulus Ægineta's description:—"That man is in the best temperament of body when it is in a medium between all extremes, of leanness and obesity, of softness and hardness, of heat and cold, of moisture and dryness; and, in a word, who has all the natural and vital energies in a faultless state. His hair also should be neither thick nor thin, neither black nor white. When a boy, his locks should be rather tawny than black, but when an adult, the contrarywise." (Adam's 'Trans.,' i. 60.)

Further information respecting the opinions of the ancients on the subject of the temperaments may be found in the treatise of Hippocrates, 'De Natura Hominis,' tom. i., ed. Kühn; in Galen's works, 'De Elementis ex Hippocrate,' tom. i., 'De Temperamentis,' tom. i., 'De Optima Corporis nostri Constitutione,' tom. iv., 'De Sanitate Tuenda,' lib. v., tom. vi., and his 'Ars Medica,' tom. i.; Oribasius, 'Synopsis,' lib. v., cap. 43, sq.; Aëtius, 'Libri Medicinales,' lib. iv., cap. 53, sq.; Haly Abbas, 'Theor.,' lib. i.; Averroes, 'Collig.,' lib. vi.; Alsaharavius, 'Theor.,' tract vi.; and Avicenna, 'Cantica.'

After the revival of letters, this fourfold division was adopted in its most essential parts by all the most eminent physiologists. Stahl ingeniously adapted it to the modern doctrines of the humoral pathology; and even Boerhaave, although he increased the number of the temperaments to eight, and relinquished the erroneous opinions of Hippocrates and Galen respecting the constitution of the blood, yet he still derived the characters of his temperaments from the principles of the humoral pathology, and supposed them to be formed merely by different combinations of the four cardinal qualities. Many late physiologists have been inclined to doubt whether the external characters associated with the four temperaments are real and constant signs of diversity in bodily structure, and enable us to distinguish the principal varieties of constitution which exist. Several attempts have accordingly been made to define in a more satisfactory manner the peculiarities of organisation and the resulting varieties of predisposition, which are chiefly interesting with regard to pathology. Hoffmann and Cullen have, indeed, retained the old division, supposing that the theory of the ancients, as to the peculiarities of constitution, was founded originally upon facts, though subsequently combined with an erroneous theory. Haller seems to have been the first who decidedly opposed the ancient doctrine, not only by showing that there was no foundation for the varieties of the temperaments in the peculiar nature of the fluids, but by substituting in their place the vital actions of the system. Darwin proceeded upon the principle of Haller; and, in conformity with the hypothesis which he adopted of reducing these actions to the four heads of irritation, sensation, volition, and association, he formed four temperaments in which these qualities were supposed respectively to prevail. The only attempt, however, to improve upon the Hippocratic theory and division which has been attended with any degree of success, is that by Dr. Gregory, who, to the four temperaments of the ancients added a fifth, which he called the *nervous*, and bestowed upon three of the others the new appellations of the *tonic*, the *relaxed*, and *muscular* temperaments. Dr. Prichard, however, restricts the number to four, and designates them by their original names; remarking that only four strongly-marked diversities of external character present themselves to observation; that the nervous temperament is not so distinguished; and that, therefore, as this is an essential part of the original scheme for the distribution of temperaments, the improvement proposed by Dr. Gregory is lame and defective. These four varieties, then, of external character really indicate, more or less constantly, well-marked differences of constitution, and, likewise, of morbid predisposition.

There is no doubt that persons having the complexion and other signs of the sanguine temperament, are more liable to certain classes of disorders than the phlegmatic or melancholic, while the latter have their own peculiar tendencies. The sanguine, having a fully-developed vascular structure, and therefore a vigorous circulation of blood, a warm skin, and a high degree of organic sensibility, are more liable to sudden and powerful impressions from external agents than those of more languid vital functions. They are subject in a greater degree to severe inflammatory disorders, and disorders of this class are in them more acute: they bear, however, better than persons of more languid habit, evacuations of blood and the other measures which are found to be the proper remedies for these diseases. The greater fulness of blood-vessels, of those at least which are near the surface, the greater warmth of the skin, and the florid complexion of the sanguine, afford reason to believe that the designation given to this temperament is not wholly unfounded. We likewise find that sanguine persons are more subject to hemorrhages (to those at least which are termed *active*) as arising from excess in the force of circulation through the arteries. Individuals of the phlegmatic temperament are predisposed to disorders arising from, or connected with, a low degree of vital energy. Local congestions of blood arising independently of general excitement come under this category. Glandular and tubercular diseases take place in bodies weak in the structures connected with the vital functions, and are perhaps more frequent in the phlegmatic than in other temperaments. Inflammatory complaints, when they attack the phlegmatic, are less acute and more disposed to terminate in chronic diseases than are those of the sanguine constitution, when at least the latter have been treated by appropriate remedies. The relations of the choleric to the melancholic temperament are similar to the relations which the phlegmatic bears to the sanguine; the former displays greater vigour, both in health and disease than the latter. The choleric and sanguine, when affected by diseases of the nervous system, have complaints of greater violence and acuteness: mania or raving madness belongs particularly (according to the observations of M. Esquirol and many others) to these constitutions. The melancholic temperament is most prone to monomania, attended with depression and melancholy illusions. Hypochondriasis much more frequently affects the phlegmatic and melancholic, though it is occasionally observed in persons who have some of the external characters of the sanguine temperament. The most severe cases of hypochondriasis, adds Dr. Prichard, and those which approached most nearly to the character of melancholia, have certainly occurred in individuals of a dark leaden complexion, fixed and sullen aspect, and lank coal-black hair.

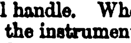
But it is not merely on the body, both in its healthy and morbid state, that the temperament exerts an important influence; the relation of the different forms of physical organisation to the intellectual and even to the moral faculties is equally marked and apparent. The relation of mental peculiarities to the structure of the body has been observed by medical authors of every age, and it has been stated and explained in different ways. Hippocrates said that "the soul is the same in all men, but that the body is different in different individuals. The soul is ever like itself both in greater and in less, for it undergoes change neither by nature nor by necessity; but the body is subject to continual alterations. The affections of the mind depend upon the body; there are many states of the latter which sharpen, and many which obtund it." (Hipp., *De Victûs Ratione*, lib. i., § 21, tom. i., p. 650.) Democritus, in a letter said to have been addressed by him to Hippocrates, asserted that "the intelligence of the mind depends greatly on the body, the diseases of which obscure the mental faculties, and draw the latter into consent." (Hipp., 'Epist.', tom. iii., p. 824.) Among the writings of Galen there is a treatise entitled 'Quod Animi Mores Corporis Temperamenta sequantur' (tom. iv., ed. Kühn), written expressly to establish the connection between the passions and desires of the mind and the temperaments, wherein he has handled the subject very ingeniously and has delivered many profound views of the animal economy. But it is in the works of modern writers that we find this doctrine most fully developed, and made a foundation for a division of human characters, though their views are mingled with many fanciful and unphilosophical speculations.

The doctrine of temperaments is true to a certain extent, and has ever been confirmed by an appeal to experience. States of the mind are so connected with affections of the body, that it is impossible for any person who considers all the physiological facts that present themselves in connection with this subject to doubt that with each temperament particular mental qualities must be associated, although it is manifest that many writers have indulged their fancy on this subject, and have gone into more full and minute details than experience will establish.

TEMPERAMENT AND TUNING. Temperament is the name given to the discussion of the subject of which tuning is the application; and tuning is the art of adjusting the several sounds of a musical instrument so as to make its scale approach to correctness; also that of putting two instruments, each of which has the parts of its scale in proper relative adjustment, into agreement with each other.

Some musical instruments have a permanent relative scale, all the parts of which, if changed at all, change together. Thus a horn or a flute may change its pitch from the heat of a room, but all the parts change together, and the whole effect of temperature is corrected at once by lengthening the pipe of which the instrument consists. Other instruments require to have the parts of their scales compared with each other from time to time, owing to their several parts being unconnected and subject to unequal wear or to separate accident, such as the organ and piano-forte. Others again are so liable to these derangements as to require tuning on every occasion of use, as the violin class, the harp, the drums, &c. It is not our intention to enter into the mode of tuning instruments in detail, but, as promised in the article SCALE, to give some account of the difficulties which are met with in the actual construction of any scale, and the ordinary modes of meeting them.

In the article just referred to we have pointed out the mathematical commencement of this subject, and have made it evident, from first principles, that *a perfect* scale* is impossible; that is to say, one in which all the intervals, or even all the principal intervals, in every key, shall be perfect. Let additional notes be introduced to make existing keys perfect, and those additional notes would themselves become the key-notes of new keys, requiring additional notes to make *them* perfect. Again, the conditions of the ordinary musical instruments require that the octave shall consist of only twelve semitones; and though some organs have been constructed with more, it is not worth while to embarrass the subject by treating of any other scale than that of the twelve semitones. We shall use the same notation as before, namely, expressing the following note of the treble scale,



by c, we shall denote the successive cs in ascent by c^1, c^2, &c., and those in descent by c_1, c_2, &c.: thus, c_3 is three octaves below c, and c^4 is four octaves above it.

The first point is to fix upon some one note, by the pitch of which all others may be determined. The only way of retaining a permanent pitch for use is by having an instrument which time will not alter. It is true that the pitch of a note depends only upon the number of vibrations in a second, and can, by the description of this number, always be recovered by acoustical experiments. But we might as well expect a carpenter to ascertain his own foot-rule for himself by the pendulum as an ordinary musician to appeal to the theory of musical vibrations. A standard pitch is usually obtained, or professed to be obtained, by the tuning-fork, an instrument consisting of two steel prongs growing out of a steel handle. When these prongs are sharply struck they vibrate; and if the instrument be then held to the ear, or placed upon the flap of a table or any other sound-board, a low and very pure sound is heard, if the prongs be perfectly equal. These tuning-forks are usually made to sound either c^1 or A, and they would answer their purpose exceedingly well if there really were in existence any standard from which they were made. But this there is not; and the consequence is, that not only do the tuning-forks of different makers frequently vary a little from each other, but the new forks are sensibly higher than the old ones. We have already seen how much the pitch used in different places varies [ACOUSTICS], and also how very much what is now called concert-pitch is higher than it was a century ago. [PIPE.] This rise, it appears, is still going on, and, unless measures be taken to stop it, will not finish until all the compositions of the old masters are played and sung two or three notes higher than they were really written.

There was, we are told, a few years ago, a standard, so called, constructed under the direction of those who manage the Philharmonic Concerts; but we are not aware that any account was given of the method of selection, or that any experiments were instituted with a view to its perpetuation. We are also told that this mysterious standard was committed to the charge of one particular tradesman, and that the rest of the craft had difficulty in obtaining it. We have seen another promulgation of a standard tuning-fork, for the especial use of singing-classes. The prospectus of the seller states that careful experiments have determined that the Philharmonic c (the c^1 of our notation) vibrates less than 512 times in a second; how much less is not stated. These new tuning-forks are asserted to have had their pitch raised to vibrate 512 times in a second; avowedly for no other reason than that 512 is a good number for calculation, and intermediate between those of tuning-forks now in use; and it is stated that every fork is tuned to the true standard by a "scientific process." But directors of concerts and publishers of music should be aware that no attention is ever paid by those who understand such matters to scientific secrets; and that until a full account is published, and authenticated copies of the standard are made secure and accessible, the science of the standard-makers will rank no higher than that of the tailors who cut "on unerring geometrical principles."

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* This means, of course, impossible so long as only twelve sounds are allowed in the octave. General Perronet Thompson, a warm advocate of the total abolition of temperament, has constructed an enharmonic organ, which is publicly exhibited, having fifty-four sounds in the octave, and perfect in twenty-one keys. All that can be said about the subject is exhausted in his 'Principles and Practice of First Intonation,' 4th edition, 1860 (Effingham Wilson), a shilling tract of 112 very full pages. We think that he overrates the admitted inconvenience; and we despair of seeing a pianoforte with fifty-four sounds which shall stand in tune, so as to preserve the minute differences of neighbouring sounds. But we decidedly approve of the attempt: and we can only say that if there shall be a general demand for the abolition of temperament, we have no doubt the thing is practicable. But a change of musical scale requires great concerted action: want of instruments puts difficulties in the way of concert, and want of concert puts difficulties in the way of getting instruments.

Mr. Woolhouse, who made experiments on this subject ('Essay on Musical Intervals,' p. 64), finds the "common pitch-note A" to make 424 double vibrations in a second, from whence he infers that C^1 gives 509 such vibrations; but whence he got this pitch-note he does not state, nor whether he was aware of the existence of a so-called Philharmonic standard. As matters stand, we should recommend every one not to be led into the belief of the existence of a standard without some better account of it than yet exists, and also in the mean time to do what he can to *keep down concert-pitch*, so as at least to prevent its rising higher than it now generally is.

There is another matter connected with the tuning-forks which requires some attention. These forks (in England, not on the Continent) are differently manufactured: there are C forks and A forks—that is, forks which sound C^1 and A. In the orchestra, which must follow the violins, the A fork is always used; while in tuning a pianoforte, harp, &c., the C fork is used. It is much to be wished that only one, the A fork, should be used. Even if the scale were perfect, it would still be desirable not to run the risk of error arising from the use of different forks; add to which, that, without extreme care,—such care as never is taken,—it is impossible to avoid making the temperament depend somewhat upon the note which is first tuned, and which must be that sounded by the fork. We do not certainly much believe in the temperament of an orchestra; the characters of the instruments are various, and the disposition of most of the wind instruments to be a little out of tune, each in one or more particular parts of the scale, gives them each something so like a temperament (or dis-temperament, if the reader please) of its own, that the united body disobeys temperament to a degree which sets the slight differences between one system and another altogether aside. In the full passages there is too much noise for the ear to be very nice on this point, and in the solos the leading instrument marks its own temperament upon the whole orchestra. But when a few instruments come together, some of which are tuned from A and others from C, the disadvantage of different temperaments may be sensibly felt. But all this must be said with much deference, for circumstances connected with the scale or its adjustment may produce very different effects on different ears.

We leave the above as it stood in the 'Penny Cyclopædia.' In 1859 the French ministry made the settlement of the musical pitch a government business: the C^1 was settled at 522 vibrations per second, which, so much had the pitch risen even in very recent time, was a considerable abatement. Also in 1859, the Society of Arts took up the subject in England, and a committee ascertained that C^1 had actually reached 546 vibrations per second. Looking at the love of singers and concerto-players for brilliancy,—which, we should explain to those unversed in music, means *squeakiness*,—there was much reason to fear that the rise was not near its end. Since 1840 the pitch had risen a semitone. For practical reasons, connected with the state of musical instruments and the want of power to enforce, the society recommended that 528 should be the number of vibrations in C^1. This proposal was generally approved of, and tuning-forks (A and C, the interval being that of equal temperament) were constructed accordingly. There is then some hope that at least all further rise will be stopped; and we cordially recommend the proposal, not without a hope that in course of time a still further fall may be found practicable.

The leading note being settled, the tuner must learn to tune that note in perfect unison with his fork, and then to tune the octaves of that note both above and below. This seems to be the most plain and straightforward part of the whole operation; nevertheless, easily as tuners take it, and readily as they refer to one of their octaves as being as good an authority as the original note itself, we cannot help thinking that more pains than is usually taken might be well bestowed. A note and its octave, when the consonance is perfectly well tuned, should sound like one note: now considering that in a grand piano there are six strings to be tuned before an octave is ready, three unisons with the lower note and three with the upper, it is not so very easy to present that perfectly indivisible effect which a good artist ought to strive for. There is a method (given in Jousse's work) of tuning the twelve semitones of one octave-interval first, without tuning the octave of any note, by proceeding upwards by fifths and downwards by fourths, until the whole is completed, and this purposely to avoid depending upon notes in the adjacent octaves. This mode, however, or any other, must be matter of individual selection: it cannot be supposed that any one method would be best suited to all ears.

Those who are acquainted with the mathematical theory of the scale know that all the concords cannot be made perfect: others may learn it in the following way:—Suppose twelve perfect fifths to be tuned upwards from C, and give the results the names of the notes which they would represent in the scale of twelve semitones, and in the nomenclature of sharps, if the scale were perfect. We should then have

$$C,\ G,\ D^1,\ A^1,\ E^2,\ B^2,\ F^3\sharp,\ C^4\sharp,\ G^4\sharp,\ D^5\sharp,\ A^5\sharp,\ E^6\sharp,\ B^6\sharp.$$

Now since $B^6\sharp$ is the same note as C^7, it appears that twelve perfect fifths should be the same as seven octaves; and if we pass to the octave below, as soon as we get out of the octave beginning with C, we should have C, G, D, A, E, &c., the last being C^1. It will be found, however, that this is not true, but that the note obtained from twelve ascents by fifths intermixed with six descents by octaves is sharper than C^1. Again, if the perfect thirds be tuned from C, we should have C, E, G♯, C^1; but it will be found that C^1 obtained in this way is too flat. The octave derived from the fifths vibrates 223 times where it should vibrate 220; and that derived from the thirds vibrates 125 times where it should vibrate 128. The slight alterations which are made in order that any one of the twelve notes of the octave may be fit to be used as a key-note, without any shock to the ear, constitute the *temperament* of a scale; the altered consonances are said to be *tempered*. Some writers call the interval from the false octave obtained by the fifths to the true one, by the name of the *wolf;* and using the word in this sense, Lord Stanhope contends (and justly) for five *wolves*, one from the fifths, and one from each of the sets of thirds beginning with C, C♯, D, D♯; and three more might have been got from the minor thirds. But by the term *wolf* other writers mean the bad fifth which exists in the worst key, when the temperament is allowed to favour some keys at the expense of others. Simple as this little variation in the meaning of a term may be, it is worth while to notice it. A writer on tuning charges some of the pianoforte-makers of his time with utter ignorance of the scale, in stipulating with the tuners whom they employed that there should be no wolf. In all probability they only meant that no key should be worse than another, or that the temperament should be equal. This term *wolf* is said to be derived from the jarring of a badly-tuned consonance, supposed to resemble the distant howling of the animal: we rather suspect it was so called because it was hunted from one part of the scale to another like a wild beast, in hopes of getting rid of it.

Two systems of temperament suggest themselves: the first, *equal*, in which the necessary defects of the scale are distributed equally throughout it; the second, *unequal*, in which some mode is adopted of distributing the imperfection so as to make some keys feel it less than others. The most common practice of our day is to endeavour at equal temperament. The two systems have their advocates, and the arguments for one and the other are as follows. In favour of equal temperament it is urged that all the keys are made equally good, and that in no one does the imperfection amount to a striking defect: also that in the orchestra there is little chance of any uniform temperament among the various instruments, if it be not this one. Against equal temperament it is urged that it takes away all distinctive character from the different keys, and leaves no one single key perfect. All these arguments have force, both for and against: for ourselves, we consider those against equal temperament much the stronger. We have often felt that a pianoforte newly tuned has, with much correctness, a certain insipidity, which wears off as the effect of the tuning gradually disappears; insomuch that the best phase of the instrument, to our ears, is exhibited during the period which precedes its becoming offensively [*] out of tune. At this time the progress towards the state of being out of tune (for which there is no single word, *maltonation* would do very well) can only be called a change of the temperament; and the several keys begin to exhibit varieties of character which, until maltonation arrives, render the instrument more and more agreeable. But it must be remarked with respect to equal temperament, that it cannot be obtained in the ordinary way of tuning. The only way, unless beats be used, of obtaining a given temperament, equal or unequal, with certainty, is to take a monochord, and having calculated the proper lengths of the different strings, to form the successive notes on the monochord, and to tune the several notes of the instrument in unison with them. No tuner can get an equal temperament by trial: so that the question lies between the having all sorts of approximations to equal temperament, according to the propensities of different ears, or as many sorts of approximations to some other systems. Had the English nation been as musical as it is mechanical, a portable monochord, or system of monochords, would have been invented, on which any given system of temperament could have been readily laid down by rule, and thence transferred to the instrument.

The mode of proceeding by approximation to equal temperament is simply to tune the fifths a little too flat, and the following order of proceeding is the most usual, and has often been given. The first letter represents the note already tuned, the second the one which is to be tuned from it: a chord interposed in parentheses represents the trial that should be made upon notes already in tune, in order to test the success of the operation as far as it has gone. The first step is to put C^1 in tune by the tuning-fork:—

C^1; C^1C; CG; GG_1; G_1D; DA; AA_1; A_1E; (CEG); EB; (CEG, DGB); BB_1; $B_1F\sharp$; $(DF\sharp A)$; $F\sharp F_1\sharp$; $F_1\sharp C\sharp$; $(A_1C\sharp E)$; $C\sharp G\sharp$; $(EG\sharp B)$; C^1F; (FAC^1); $FA_1\sharp$; $(A_1\sharp DF)$; $A_1\sharp A\sharp$; $A\sharp D\sharp$; $(D\sharp GA\sharp$; $D\sharp G_1\sharp$; $(G_1\sharp CD\sharp)$.

We have written all the semitones as sharps, whether tuned from above or from below. Of course, since the fifths are all to be a little too small in their intervals, the upper note must be flattened when tuned from below, and the lower note sharpened when tuned from above. In the preceding, the octave CC^1 is completely tuned, and also the adjacent interval F♯C. The rest of the instrument is then to be tuned by octaves. The thirds should all come out a little sharper than perfect, as the several trials are made: when this does not happen, some of the preceding fifths are not equal. The parts which are first tuned by the fifths, and from which all the others are tuned by octaves, are called *bearings*.

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[*] A musical critic has stated that we avowedly prefer an instrument *out of tune.* His mistake probably arises from his confounding *equal temperament* with *perfect tune*, average sin with perfect holiness: perhaps he did not know that any scale with twelve sounds cannot be in perfect tune in every key.

We shall now show how, by means of the theory of the scale, to examine a system of temperament: the rest of this article is therefore only for those who have some mathematical knowledge of the scale. Everything will be expressed in mean semitones, and the following additions will be convenient:—A major tone is 2·039100 mean semitones; a minor tone, 1·824037; a diatonic semitone, 1·117313; a comma, ·215063; the excess of twelve perfect fifths above seven octaves, ·234600, a little more than a comma, frequently called a comma; the excess of an octave above three perfect thirds, ·410689. Various modes of dividing the octave have been proposed—that is, of creating imaginary subdivisions—by means of which to express the various intervals required. None is so convenient, in our opinion, as the expression by means of mean semitones and their fractions.

We prefer to show a complete examination of one system, in such a manner that any one may apply it to another, instead of briefly noting the peculiarities of different systems. We shall take as an example Dr. Young's first system, which is as follows:—Tune downwards, from the key-note, six perfect fifths, ascending into the octave interval CC^1 when necessary: then tune upwards, from the key-note, six equally imperfect fifths, throwing the whole error of ·2346 of a mean semitone equally among them. In the equal temperament the wolf is made to bear twelve cubs: here only six—larger ones of course. Now a perfect fifth, being two major tones, a minor tone, and a diatonic semitone, is thus composed:—

Two major tones . .	4·078200 mean semitones
Minor tone . . .	1·824037
Diatonic semitone . .	1·117313
Perfect fifth . . .	7·019550

The imperfect fifth of this temperament is to be flattened by the sixth part of ·234600, or ·039100, and 7·019550 – ·039100 is 6·980450, the imperfect fifth required. We are then to proceed as follows:—

Six fifths downwards perfect.			Six fifths upwards imperfect.		
	C^1	12·00000		C	0·00000
		7·01955			6·98045
1.	F	4·98045	1.	G	6·98045
	F^1	16·98045			6·98045
		7·01955			
				D^1	13·96090
2.	A♯	9·96090	2.	D	1·96090
		7·01955			6·98045
3.	D♯	2·94135	3.	A	8·94135
	D^1♯	14·94135			6·98045
		7·01955			
				E^1	15·92180
4.	G♯	7·92180	4.	E	3·92180
		7·01955			6·98045
5.	C♯	0 90225	5.	B	10·90225
	C^1♯	12·90225			6·98045
		7·01955			
				F^1♯	17 88270
6.	F♯	5·88270	6.	F♯	5·88270

There is no doubt, at least in this world,* much surplusage in carrying the results to five decimals, or the hundred-thousandth part of a mean semitone; but all calculators are aware of the desirableness of using more places than will ultimately be wanted. Collecting the above results, we have, for the interval of every note from C, as far as C^1, as follows:—

C	0·00000	E	3·92180	G♯	7 92180
C♯	0·90225	F	4·98045	A	8·94135
D	1·96090	F♯	5·88270	A♯	9·96090
D♯	2·94135	G	6·98045	B	10·90225

We shall now examine the effect upon the several keys. We have remarked [SCALE], that the effect of making an interval too small is to render the consonance of a more plaintive character; while we may suppose that too large an interval has a somewhat contrary effect. As the most important chord of every key is that of the key-note, its third, and fifth, we must form our idea of the effect of each key from observing the effect of the temperament upon the common chord of the key-note, judging of the character of the key by the amount and direction of the temperament of the third and fifth. Now a major third is made of a major and minor tone, and is therefore 3·86314 mean semitones; while a minor third, or a major tone, and a diatonic semitone, is 3·15641 mean semitones. Hence the principal chord of a key, according as it is major or minor, has the following intervals from the key-note:—

Major	3·86314,	7·01955
Minor	3·15641,	7·01955

To examine any particular key, take out the numbers from the preceding table opposite to the notes of the principal chord (adding 12 to make the octave when necessary); subtract the number of the key-note from each of the other two, and the remainders will give the tempered intervals. Compare the tempered intervals with the preceding correct intervals, and the amount and direction of the temperament will be seen. For instance:—

Key of A major.

A 8·94135	C^1♯ 12·90225	E^1 15·92180
	8·94135	8·94135
Tempered intervals . . .	3·96090	6·98045
Perfect intervals	3·86314	7·01955
Temperaments . . .	+·09776	—·03910

and + means sharper than perfect, — flatter than perfect. We might describe this chord (keeping three decimals, which is more than sufficient) as having a temperament expressed by the following symbol (+ ·098 — ·039); and if we examine all the keys in the same manner, we shall have the following account of this system of temperament. (A person who is used to the subject, and to calculation, might proceed more shortly by considering the law of the system, but the beginner had best take each key by itself. We have preserved the use of sharps only, for the sake of symmetry.)

Major Key.	Temperament.	Minor Key.	Temperament.
C, D, G	(+·059, –·039)	A, B, E	(–·098, –·039)
C♯, F♯, G♯	(+·215, 0)	A♯, D♯, F	(—·215, 0)
D♯	(+·176, 0)	C	(—·215, —·039)
E	(+·137, –·039)	C♯	(—·137, 0)
F	(+·098, 0)	D	(—·137, —·039)
A	(+·098, —·039)	F♯	(—·098, 0)
A♯	(+·137, 0)	G	(–·176, —·039)
B	(+·176, —·039)	G♯	(—·176, 0)

The rules for the verification of every such process are six in number, and as they express relations which may be made of signal use in searching for systems of temperament, we give them at length. In all these rules it is supposed that the fifths and minor thirds are tempered flat, the major thirds sharp, and that the signs are neglected.

1. The sum of the temperaments of all the fifths in the twelve keys must be the excess of twelve fifths above seven octaves, or ·23460 of a mean semitone.

2. The sum of the temperaments of all the thirds in the twelve major keys must be the excess of the octave above three major thirds taken four times, or 1·64236 mean semitones; the sum of the temperaments of the thirds in any three keys whose tonics are successive thirds being the excess above mentioned, or ·41059 of a mean semitone.

3. The sum of the temperaments of all the thirds in the twelve minor keys is three times the excess of four minor thirds over an octave, or 1·87695 mean semitones; the sum of the temperaments of the thirds in any four minor keys whose tonics are successive minor thirds being the excess above mentioned, or ·62565 of a mean semitone.

4. The temperament of the third in any major key, increased by the temperaments of the fifths *in that key and* the three succeeding dominant keys, makes a comma, or ·215063 of a mean semitone. The *dominant* of a note is the fifth above it; so that the successive dominant keys of C major, for instance, are those of G, D, A. Thus, in the above system, the temperament of the third in A♯ major is ·137, and those of the fifths in A♯, F, C, G, are 0, 0, ·039, ·039: put these together, and we have ·215, a comma, as asserted.

5. The temperament of the minor third in any key, together with the temperaments of the fifths *in the three succeeding* subdominant keys, make a comma, or ·21506 of a mean semitone. The subdominant of a note is the fourth above it; so that the successive subdominant keys of C, for instance, are those of F, A♯, D♯. Thus, in the above system, the temperament of the third in A♯ minor, for instance, is ·215, and the temperaments of the fifths in D♯, G♯, C♯, are severally 0: these put together of course give ·215, a comma, as asserted.

6. The temperament of the flat seventh in any key is the difference of those of the fifth in that key and the minor third in the dominant key.

The algebraist may easily see how these rules are deduced, and also that they are all which can be obtained. They amount altogether to 25 equations of condition; for the first, fourth, and fifth rules contain the second, third, and sixth. Now, the pitch note C^1 being given, there are eleven notes to be determined, and there are 3 × 12 or 36 equations between the values of those notes and the temperaments of the major thirds, minor thirds, and fifths. But 36 equations between the eleven values of the notes should give 25 equations between the values of the temperaments; and these 25 equations are contained in our first, fourth, and fifth rules.

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* Mr. Marsh, the author of a treatise on tuning, is seriously of opinion that a perfect scale is one of the blessings reserved for a future state, in which "it will be part of the enjoyment of the blessed to chant the praises of their Creator in extatic hallelujahs, *when systems of tuning shall no longer perplex us, and temperament shall be no more.*"

In every system of temperament which deserves the name, the fifths must be flattened, and also the minor thirds; while the major thirds must be sharpened. In any other case, the algebraist might use the preceding rules by considering as *negative* the temperament of a sharpened fifth or minor third, or of a flattened third. In this sense, these rules are always true, from the instant when the strings of the instrument are put on, and throughout its existence as a sounding body.

It is now easy to determine the temperaments of the thirds, major and minor, from those of the fifths. From a comma subtract the sum of the temperaments of the fifths in any one key and the three following dominant keys, and the remainder will be the temperament of the major third in that key. Again, from a comma subtract the sum of the temperaments of the fifths in the three subdominant keys following any given key, and the remainder will be the temperament of the minor third in that key. Hence we may, without any trouble, lay down at pleasure the temperaments of the fifths, and deduce those of the thirds. But we cannot, from the temperaments of the thirds, deduce those of the fifths. It must be remembered that a succession of fifths, setting out from a given note, runs through every note of the scale before it reaches that note again; while the major thirds are brought up, so to speak, by the original note, in three successions, and the minor thirds in four. There are then four distinct parcels of major thirds, and three of minor ones, so that it is impossible to pass out of one into another by thirds alone. It would be possible to temper *all* the major thirds equally, and yet to retain an unlimited number of modes of tempering the fifths, depending upon the manner in which one system of thirds is joined on to the others; and the same of the minor thirds.

We have, from the scale, shown how to construct the temperaments: we now take the inverse question, namely, from the temperaments to construct the scale. Let the sharps be denoted by accents placed above the letters: thus A' represents A♯, and so on. Let the temperaments of the fifths, in the several keys, be denoted by the small letters: thus a represents the temperament of the fifth in the key of A, or is the portion of a mean semitone by which the interval from A to E falls short of a perfect fifth. And, for abbreviation, let simple commas denote addition: thus a, b may mean $a + b$. Also let the notes themselves be descriptive of their intervals from C: thus C means 0; G' means the interval between G♯ and C: we have, then, V meaning the number of mean semitones in a perfect fifth,

$$\begin{aligned}
\text{C} &= 0 \\
\text{G} &= \text{V} - c \\
\text{D} &= 2\,\text{V} - 12 - c, g \\
\text{A} &= 3\,\text{V} - 12 - c, g, d \\
\text{E} &= 4\,\text{V} - 24 - c, g, d, a \\
\text{B} &= 5\,\text{V} - 24 - c, g, d, a, e \\
\text{F}' &= 6\,\text{V} - 36 - c, g, d, a, e, b \\
\text{C}' &= 7\,\text{V} - 48 - c, g, d, a, e, b, f' \\
\text{G}' &= 8\,\text{V} - 48 - c, g, d, a, e, b, f', c' \\
\text{D}' &= 9\,\text{V} - 60 - c, g, d, a, e, b, f', c', g' \\
\text{A}' &= 10\,\text{V} - 60 - c, g, d, a, e, b, f', c', g', d' \\
\text{F} &= 11\,\text{V} - 72 - c, g, d, a, e, b, f', c', g', d', a'
\end{aligned}$$

That is, the interval from C to B, for example, is found by deducting from the excess of five perfect fifths above two octaves the sum of the temperaments of the fifths in the keys of C, G, D, A, and E. Towards the end, in isolated questions, trouble will be saved by remembering that the sum of all the temperaments of the fifths is ·2346 of a mean semitone, and that we thus have—

$$\begin{aligned}
c, g, d, a, e, b, f', c', g', d', a', &= {\cdot}2346 - f \\
c, g, d, a, e, b, f', c', g', d', \quad &= {\cdot}2346 - f, a', \text{ \&c.}
\end{aligned}$$

We shall now take an example of this, and our instance shall be the proposal of a system of temperament which we should like much to see tried. We are for variety in the several keys, and against equal temperament; but we do not like variety without law. We do not like, for example, to find the greatest temperament in one key, and the least in an adjacent key, as that of the dominant or subdominant. Suppose, then, we ask what can be done towards an ascending and descending temperament, which, proceeding, say from the key of C, shall increase through the keys of C, G, D, A, E, B, and diminish through those of F', C', G', D', A', F. And, as a first step, let the increments and decrements of the temperaments of the fifths be equal, or let $c = m$, $g = 2m$, $d = 3m$, $a = 4m$, $e = 5m$, $b = 6m$, $f' = 7m$, $c' = 6m$, $g' = 5m$, $d' = 4m$, $a' = 3m$, $f = 2m$. Here, as far as the fifths are concerned, the effect of modulation into the dominant or subdominant keys is the same everywhere, as much as in equal temperament. And, from the first rule, we have $48m = {\cdot}2346$, or $m = {\cdot}0048875$, and the greatest temperament of a fifth is seven times this, or ·034. Now, if we compute the temperaments of the thirds, major and minor, from the fourth and fifth rules, we may exhibit the temperaments of all the keys, as follows:—

Key.	Temperament.			Key.	Temperament.		
	−	+	−		−	+	−
C	·166	·166	·005	F♯	·127	·108	·034
G	·191	·147	·010	C♯	·122	·127	·029
D	·186	·127	·015	G♯	·127	·147	·024
A	·171	·108	·020	D♯	·142	·166	·020
E	·156	·098	·024	A♯	·156	·176	·015
B	·142	·098	·029	F	·171	·176	·010

The three columns contain the temperaments of the minor third, major third, and fifth. The effects of modulation into adjacent keys are everywhere very small, nowhere amounting to more than about the tenth of a comma, in alteration of temperament; while the fifths are in different keys so differently tempered, that in C that interval may be called perfect; while in F♯ there is nearly twice as much temperament as in the equal semitone system. There is then variety without sudden change. In the system of equal semitones, the temperaments of the minor third, major third, and fifth, are always

$$- {\cdot}156, + {\cdot}137, - {\cdot}020.$$

Now, to form the scale in this system. Proceeding by the table given above, of which we take a few steps as an example, we have—

$$\begin{array}{rl}
\text{C} = & 0{\cdot}000000 \\
\text{V} = & 7{\cdot}019550 \\
\hline
 & 7{\cdot}019550 \\
c = m = & {\cdot}004888 \\
\hline
\text{A} = & 7{\cdot}014662 \\
\text{V} = & 7{\cdot}019550 \\
\hline
 & 2{\cdot}034212^{*} \\
a = 2m = & {\cdot}009775 \\
\hline
\text{D} = & 2{\cdot}024437, \text{ \&c.}
\end{array}$$

Proceeding in this way, we find for the intervals of the several semitones from the key-note, expressed in mean semitones, the following table:—

C	0·000	E	4·029	G♯	7·990
C♯	1·000	F	4·990	A	9·029
D	2·024	F♯	6·015	A♯	9·985
D♯	2·985	G	7·015	B	11·024

To carry this or any other system strictly into practice without comparisons with the monochord, or the use of beats, presently described, would be impossible; but the following might be suggested as an approximation. In tuning by fifths, let the intervals C G and F C be made perfect, or all but perfect; let there be greater temperament in G D, D A, and D♯ A♯, A♯ F; and most of all, decidedly, in the remaining intervals.

The system of temperament is sometimes described by giving the number of vibrations made by the several semitones, or numbers proportional to them. It is easy enough to deduce the number of mean semitones in each interval from such data, either by the common tables of logarithms, or by that given in SCALE.

First, by the common table of logarithms. From the logarithm of the number answering to the higher note, subtract that answering to the lower; from the result take its three-hundredth part, and multiply the remainder by 40. The product is the number of mean semitones in the interval, with an excess of very little more than the thousandth of a mean semitone in an octave. For example, to find the intervals, in mean semitones, of a fifth and of a comma; in the former of which the lower note makes two vibrations while the higher makes three, and in the latter 80, while the higher makes 81:—

For the Fifth.

$$\begin{array}{rl}
\text{log. } 3 = & {\cdot}47712 \\
\text{log. } 2 = & {\cdot}30103 \\
\hline
300) & {\cdot}17609 \\
 & {\cdot}00059 \\
\hline
 & {\cdot}17550 \\
 & 40 \\
\hline
\text{Result} & 7{\cdot}02 \\
\text{More exactly} & 7{\cdot}01955 \\
\hline
\text{Error} & 0{\cdot}00045
\end{array}$$

For the Comma.

$$\begin{array}{rl}
\text{log. } 81 = & 1{\cdot}90849 \\
\text{log. } 80 = & 1{\cdot}90309 \\
\hline
300) & {\cdot}03540 \\
 & {\cdot}00002 \\
\hline
 & {\cdot}00538 \\
 & 40 \\
\hline
\text{Result} & {\cdot}2152 \\
\text{More exactly} & {\cdot}2151 \\
\hline
\text{Error} & {\cdot}0001
\end{array}$$

Next, by the table in SCALE. If the numbers be in the table, simply subtract the logarithm of the lower number from that of the higher, and the result is the answer required, within about the hundredth of a mean semitone. But if the numbers be not in the table, divide both by any number which will bring them within the table, accurately or approximately, and then subtract as before: inter-

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[*] Throw out the twelves as fast as they arise.

polation may of course be employed, but if the skill of the computer do not reach so far, he must be content with a less accurate result, or must use the common table, in the manner just explained. For instance, one note makes 4622 vibrations, while another makes 5033; required the interval between them. Divide both by 30, which gives 154·1 and 167·8; if without interpolation, say 154 and 168. Opposite to 168 is 88·70, and opposite to 154 is 87·20, differing by 1·5, or a mean semitone and a half. The interpolated logarithms are 88·68 and 87·21, differing by 1·47. The more accurate result of the former rule is 1·4752.

The tuning of a piano-forte is generally done by ear, but in that of an organ recourse is had, though not very often, to the beats which imperfect consonances always give. In the temperament of this last-named king of instruments, less liberty is allowable than in that of the stringed instruments; for not only do the beats become unpleasantly frequent when a consonance is too imperfect, but the imperfection of the consonance itself is more perceptible when notes are held, as in the organ, than when they die rapidly away, as in the piano-forte. These beats are described in ACOUSTICS, and when the lower note is known, and also its number of vibrations, the number of beats which are made in a given time, as ten seconds, a minute, or any other which is convenient, can be calculated from the known imperfection of the consonance, and the number of vibrations of the lower note. Theoretically speaking, it makes some little difference whether the consonance be tempered sharp or flat, but not to an extent which it is worth while to consider. The rule for determining the beats is as follows: let the lower note of the (perfect) consonance make n vibrations, while the upper note makes m, the fraction $m \div n$ being in its lowest terms, and let N and M be the actual numbers of vibrations in the lower and higher notes, per second: then $mN = nM$. Let μ be the fraction of a mean semitone by which the consonance is tempered; then the number of beats in a minute is found by taking the fraction μ of the production mN or nM, multiplying by 1109 and dividing by 320, or by 4, 8, and 10. The algebraical formula is

$$\frac{1109}{320}\,\mu m N \text{ or } \frac{1109}{320}\,\mu n M \left(\frac{1109}{320} = 3{\cdot}4656\right)$$

For example, let the note C^1 make 512 vibrations; it is required to find the number of beats per minute in the consonance C^1G^1, when tempered as in the system of mean semitones. Here $N = 512$, $m = 3$, $mN = 1536$. The perfect fifth is 7·01955 mean semitones, whence the fraction μ is ·01955, since the tempered fifth has seven semitones exactly. Multiply ·01955 by 1536, which gives 30·0288; multiply by 1109 and divide by 320, which gives 104·07 (say 104) beats in a minute.

Tables for facilitating the calculations might easily be made, but it is hardly worth while to insert them here. These beats are usually, we believe, simply counted with a watch, but it would be both convenient and exact to have some such machine as Dr. Smith recommended, a pendulum which could be easily altered in vibration, and first adjusted to move exactly with the beats; the pendulum might then be subsequently compared with the watch. Without such a contrivance it is very difficult to tune the piano-forte by beats, since they do not last long enough in sufficient intensity; with it the last-named instrument might easily be tuned on any system of temperament; and those who practise the art would have the advantage of hearing different systems, knowing at the same time what those systems are. At present the few organ-builders who use beats are the only tuners who make any approach to science: all the rest judge only by the ear, which may vary from time to time, or even with the state of the body, or the weather. We have many reasons for thinking that the ear alone is a variable judge in so nice a matter as temperament.

Persons desirous of information on this subject may consult Jousse 'On Temperament,' London, 1832; Hamilton, 'Introduction to the Art of Tuning' (no date); Stanhope, 'Principles of Tuning,' 1806; Marsh, 'Theory of Harmonics,' 1809; Woolhouse, 'On Musical Intervals,' 1835; Sir J. Herschel, 'On Sound' (*Encyclop. Metropol.*); Young's 'Lectures,' vol. i., cap. 33; Smith, 'On Harmonics,' first edition, 1749; second edition, 1759. This work of Dr. Smith is most difficult and confused, but is still the most extensive separate treatise on the subject; that of Mr. Woolhouse is sufficient, and much more intelligible. On the subject of beats, and on several proposals as to temperament, see a paper by Professor De Morgan, 'On the Beats of Imperfect Consonances' (*Camb. Phil. Trans.*, vol. x., part i.).

TEMPERATURE. [ATMOSPHERE; CLIMATE; ISOTHERMAL LINES.]

TEMPERATURE OF THE SEA. [SEA.]

TEMPERATURE, TERRESTRIAL, DISTRIBUTION OF. [TERRESTRIAL TEMPERATURE.]

TEMPERING OF STEEL. [STEEL MANUFACTURE; CUTLERY.]

TEMPLARS, KNIGHTS TEMPLARS, or KNIGHTS OF THE TEMPLE, are the popular designations for the Brethren of the Temple of Solomon at Jerusalem, also called the Soldiery of the Temple (*Militia Templi*) and the Soldiers of Christ. The three great religious military Orders, the Knights of the Hospital of St. John of Jerusalem (commonly called the Knights Hospitallers), the Templars, and the Teutonic Knights of St. Mary of Jerusalem (or German Knights of the Cross), all originated in the 12th century; the two former towards its commencement, during the first crusade, the last not till near its close. The founders of the Order of the Templars, which is held to date from the year 1118 or 1119, were nine knights, all French, of whom the two chief were Hugues de Payens (or de Paganes) and Geoffroi de St. Omer (or St. Ademar). One account makes all the nine to have been previously members of the Order of St. John; but it is at least doubtful if this were the case. At all events, the Hospitallers were not yet a military order; their distinguishing profession was to entertain pilgrims and to attend the sick and wounded: the idea of adding to the three common vows of chastity, poverty, and obedience, an engagement to fight against the Infidels, appears to have been first put in practice by De Payens and his brethren. Up to this time, when a knight entered the society of the Hospitallers, he seems to have laid aside his arms. Nor probably did the nine knights forming the new association at first contemplate either the extensively military character which their order eventually assumed, or even the establishment of an order which should extend and perpetuate itself. Their original vow was simply to maintain free passage for the pilgrims who should visit the Holy Land; and they did not proceed to add to their number till six or seven years after their association. In another respect, also, their early condition and pretensions were remarkably contrasted with their subsequent state; for at this time they made the greatest show of poverty, even De Payens, who was styled Master, and his friend De St. Omer, keeping only one horse between them, a circumstance commemorated in the seal of the order, which represents two armed knights mounted one behind the other on the same horse. Indeed, the name which they took, and by which they were commonly known, was the Pauper Soldiers (*Pauperes Commilitones*) of the Temple of Solomon; and they professed to have no source of subsistence but the alms of the faithful. The king of Jerusalem, Baldwin II., gave them their first place of residence—a part of his palace; to which the abbot and canons of the church and convent of the Temple, which stood adjoining, added another building for keeping their arms, whence they acquired the name of Templars.

The new principle of their association, however, immediately drew general attention; so much so, that in 1120 the Hospitallers got their order remodelled by Pope Calixtus II. on the same principle. The first regular embodying of the Templars was by Honorius II., who in 1128 confirmed a rule for them which had been drawn up and decreed that same year by the Council of Troyes, on the requisition of Hugues de Payens and several of his brethren. Honorius at the same time, to distinguish them from the Hospitallers, who were arrayed in a black mantle, assigned the brethren of the new order a white mantle for their peculiar dress, which they wore plain till Eugenius III., in 1146, appointed them to wear a red cross on the left breast, in imitation of the white cross worn by the Hospitallers. This bloody cross was also borne upon their banner, which was formed of cloth striped black and white; whence it was called *Bauseant*, an old French term applied to a horse marked with these colours. This word consequently became the famous war-cry of the Temple chivalry.

The new order speedily rose into consideration. Members of the noblest families in every nation of Christendom eagerly sought to be joined to it; legacies and donations in lands and money were showered upon it by persons of all ranks; and in course of time it acquired ample possessions in nearly every country of Europe. At the head of the order was the Master, or Grand Master (*Magister*, or *Magnus Magister*), who was, however, not only elected by the Chapter, or general body of the Knights, but very much controlled by that body. The Grand Master had immediately under him his Seneschal, or lieutenant, and other high officers were the Marshal, the Treasurer, &c. The several countries in Asia and Europe in which the order had possessions were denominated Provinces; and each of them was presided over by a resident chief, called, indifferently, a Grand Prior, Grand Preceptor, or Provincial Master. Under the provincial masters were the Priors, otherwise called Bailiffs, or Masters, who had charge each of one of the districts into which the province was divided; and, finally, under the priors were the Preceptors, each of whom presided over a single house of the order (or sometimes over two or three adjoining houses which were considered as one establishment), hence called a Preceptory. The head province was that of Jerusalem; the affairs of the order, in fact, were for the most part directed by the chapter of this province, which was invested by the constitution with all the powers of a general chapter at all times when such a chapter was not assembled. The Grand Prior of Jerusalem was ex-officio treasurer of the order; and in this province the Grand Master resided so long as the Christians retained any footing in the country; and on the fall of Acre, and the final extinction of the Latin power in Palestine, in 1192, the Knights took refuge in the town of Limisso (otherwise called Limasol) in Cyprus. The other provinces in the East were Tripolis and Antioch; to which Cyprus, till then included in one of these, was added after that island became the head-quarters of the order. The western provinces were Portugal, Castile and Leon, Aragon, France and Auvergne, Normandy, Aquitaine or Poitou, Provence, England (in which Scotland and Ireland were included), Germany, Upper and Central Italy, Apulia, and Sicily.

For some time after its institution, the Order of the Templars consisted exclusively of laymen; but in the year 1162, the famous bull entitled 'Omne Datum Optimum,' issued by Pope Alexander III., among other important privileges which it bestowed upon the order permitted it to receive as members any spiritual persons who were not bound by previous vows. These spiritual members were called Chaplains. They did not fight, nor take the military vow; but, in lieu of that duty, they not only celebrated mass and other religious offices in the houses of the order, but usually also acted as secretaries to the chapter. Alexander's bull also allowed the order to have its own burial-grounds; released it from all spiritual obedience, except only to the holy see; freed it from the payment of tithes, and even authorised it to receive them if the bishop gave his consent; and prohibited any one who had once become a Templar from ever leaving the order unless to enter into a stricter one.

At a date a little later the society still farther extended its scheme and its influence, by admitting as members many persons who were not knights or of noble birth, but who were desirous of participating in the advantages of belonging to so powerful a body, on condition of acting as the squires and servants of the knights. These were styled Serving Brethren; and in this class were sometimes found individuals both of great wealth and eminent station, though not of high birth or knightly rank. The serving-brethren, however, could not be preceptors, or hold any of the higher offices in the order. Latterly, they were divided into two classes—those of arms and those of trades; the former attending the knights to the field as esquires; the latter exercising various handicrafts in the houses or on the lands belonging to the order. The order also associated to itself many persons under the name of Affiliated Members, who took no vows, assumed no peculiar dress, nor became subject to any duties or services; but, continuing to pursue their ordinary secular occupations, merely purchased enrolment in the ranks of the powerful and highly-privileged soldiery of the Temple for the sake of the protection and other advantages, both temporal and spiritual, which even such a mere nominal membership ensured. The affiliated comprehended women as well as men. Finally, there were the *Donati* and the *Oblati*, consisting of children dedicated to the order by their parents or other relations; and also of persons of all ranks, both laity and clergy, who, without entering the order, pledged themselves to stand by it, and to maintain its rights.

The history of the Knights Templars would embrace the history of the wars of the Christians against the Infidels in the East for all the time they lasted after the establishment of the order. For more than a hundred and seventy years the soldiers of the Temple formed the most renowned portion of the Christian troops, and almost every encounter with the enemy bore testimony to their unequalled prowess and daring. But it may nevertheless be questioned whether the establishment of this and the other religious military orders proved advantageous to the attempt so perseveringly made to wrest the Holy Land from the dominion of the Infidels. The Templars and Hospitallers probably damaged and weakened the cause for which they fought, as much by their rivalry, jealousies, and frequently open contention, as they aided it by their valour. Then, the immense wealth and worldly power which the Templars in particular speedily acquired, altogether changed the original character and spirit of their institution long before it was half a century old. Within thirty or forty years from the origin of the order, two at least of the four vows which the members still continued to take had become a mockery and a profanation; instead of poverty and chastity, they were already distinguished by their pomp and pride, and the general luxury and licentiousness of their lives. But the vast material forces of the association, the extent to which it had projected its ramifications in all directions, and its other elements of strength, might have long withstood the principle of corruption thus at work within it, if it had not drawn upon itself an assault from without by which it could not fail to be overpowered.

The destroyer of the Templars was the resolute and vindictive Philip IV. of France. Philip, who came to the throne in 1285, at the age of seventeen, was the enemy of the church by education, by temper, and by circumstances. He had already proceeded to extremities in a quarrel with Pope Boniface VIII., which was terminated only with the life of that pontiff. His successor, Benedict XI., is supposed to have been poisoned at the instigation of Philip. Benedict was succeeded by Clement V., who is believed to have purchased his elevation from Philip on condition, among other compliances, of co-operating with him in the destruction of the Templars. This was in 1305. In 1306, Jaques de Molay, the Master of the Temple, was drawn to Europe by a summons from the pope, who professed a desire to consult with him on the expediency of a union of the two orders of the Templars and the Hospitallers. The following year, while Molay was at Paris, the first distinct accusations against the Templars were made by two individuals lying in prison under sentence of death; Squin de Flexian, who had formerly been a member of the order and prior of Montfaucon, but had been ejected for heresy and other offences, and a Florentine called Noffo Dei, also, according to one account, a degraded Templar, by general admission a person of the worst character. They made their revelations to Philip himself, and were immediately liberated from prison. Their charges, imputing to the order the systematic practice and encouragement of all sorts of secret immoralities, as well as the strangest confusion of heresy, idolatry, and infidelity, are far too absurd for examination. Very soon after this, on the 12th of September, 1307, royal letters were issued, sealed, to all the governors of towns and other officers of the crown in authority throughout the kingdom, and transmitted along with orders to them to arm themselves and the persons under their command on that day month, and then to open the letters in the night, and to act as they should find themselves therein directed. The result was, that the next day (Oct. 13) nearly all the Templars in France, De Molay included, were in custody. Their houses and goods were also everywhere seized; the vast stronghold of the Temple at Paris, the chief seat of the order in that kingdom, was entered and taken possession of by Philip himself.

An act of accusation was forthwith published; and Philip at the same time wrote to the pope, and also to the king of England, intimating what he had done, and calling upon them to second him. Edward II., on receiving letters from Clement, yielded, and the English Templars were seized and thrown into confinement about the end of December. Meanwhile, the examinations had been going on in France under the direction of the king's confessor, Imbert, a Dominican priest, and, as such, the inveterate enemy of the order of the Templars. Confessions, in many cases incredible from their inherent absurdity, were extracted from many of the knights at Paris and elsewhere by the most savage tortures. This went on for many months. In August, 1308, Clement, whose person Philip had now contrived to get completely into his power, issued a bull, calling upon all Christian princes and prelates to aid him in examining into the guilt of the order; and about the same time his holiness appointed a commission, consisting of the archbishop of Narbonne and other prelates and dignitaries of the church, to meet at Paris to try the case. This commission, however, did not commence its sittings till the 7th of August, 1309. A few months later, examinations under judges, deputed or nominated by the pope, commenced in England and other countries. Altogether many hundreds of knights were examined by these commissions during the years 1309, 1310, and 1311; but it was only in France, where torture was made use of, that any admissions were obtained of the crimes laid to the charge of the order, except such as were manifestly unworthy of regard. Even the Paris commission, however, did not satisfy the impatience of Philip: on its requisition a great number of knights stood forward to defend the order, among whom were several of those who had confessed and afterwards retracted. Philip, having forced the pope to nominate Philip de Marigni, bishop of Cambray, the brother of Enguerrand de Marigni, his prime minister, to the archbishopric of Sens, which had just become vacant, and then included the diocese of Paris, got the new archbishop to convoke his provincial council in the capital, on Sunday, the 10th of May, 1310; and this body, on the Wednesday morning following, had fifty-four of the defenders of the order, who had formerly made confession, brought out as "relapsed heretics" to a field behind the abbey of St. Antoine, and there committed to the flames. They all died asserting their innocence and that of the order. These proceedings and others of a like kind in the provinces of Rheims and Sens, put a stop to the attempt at defending the order: the rest of the knights who had undertaken this task now all declared their renouncement of it. Meanwhile, a general council met by order of Clement at Vienne, October 13, 1311, but it was not found so compliant as Philip and the pope had expected; and Clement, having put an end to the session, assembled the cardinals and a few other prelates upon whom he could depend, in a secret consistory, and abolished the order by his own authority, on the 22nd of March, 1312. The bull of abolition was formally published on the 2nd of May following. On the 18th of March, 1314, Molay, the grand master, and Guy, commander or grand prior of Normandy, who had all this while remained in prison at Paris, were brought before the archbishop of Sens, condemned to death, and burned on one of the small islands in the Seine, about the spot where the statue of Henry IV. is now erected on the Pont Neuf.

After all, Clement and Philip, the former of whom died suddenly about a month, and the latter, of a fall from his horse, within a year after the martyrdom of De Molay, were able to secure to themselves only a small portion of the plunder which they had probably hoped for. The king of France seized and kept, or divided with his confederate, the moveable property of the Templars in that country; but there, and also in England, and throughout the rest of Europe, with the exception of Spain and Portugal, it was found necessary to transfer their landed possessions to the Hospitallers, or Knights of St. John (at this time commonly known, from the place where they had fixed their head residence, as the Knights of Rhodes). In Spain, the lands of the Templars were bestowed upon the Knights of Our Lady of Montesa, a new order, founded in 1317; and in Portugal the society merely took the new name of the Order of Christ, which still subsists.

It has been calculated that the entire revenues of the order when it was dissolved did not fall short of six millions sterling, though it seems impossible that this should not be a great exaggeration. Their possessions in England were even at a comparatively early period of great extent and value, as may be seen from an "inquisitio," or account of their lands, taken by royal authority in the year 1185, which Dugdale has printed in his 'Monasticon' (vol. vi., pt. ii.). They are supposed to have been settled in the Old Temple, at London, which stood on the south side of Holborn, near the present Southampton Buildings, by the beginning of the reign of Stephen: they removed to their new house at the western extremity of Fleet Street, the site of which still retains the name of the Temple, in 1185. This was the chief seat of the order in England.

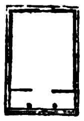
The question of the guilt or innocence of the Templars has been much discussed in modern times; and although it may be said to be now almost universally admitted that the particular charges upon which they were condemned were for the most part entirely unfounded, some attempts have been made to show the probability that the order nevertheless was held together by certain secret principles or doctrines which made its existence dangerous to society, and called for its suppression. Von Hammer, for instance, in a disquisition printed in the sixth volume of his 'Mines de l'Orient,' has attempted to convict the order of a participation in the apostacy, idolatry, and impiety of the Gnostics and Ophianites. Von Hammer's Essay was answered by M. Raynouard, in a long note printed in the fifth volume of Michaud's 'Histoire des Croisades,' &c.; and also in two articles in the 'Journal des Savans' for March and April, 1819; and in two others published in the 'Bibliothèque Universelle,' tom. x. The documents relating to the condemnation of the Templars were first published in a work entitled 'Traitez concernant la Condemnation des Templiers,' par M. Du Puy, 8vo, Paris, 1654; reprinted, with additions, under the title of 'Histoire de la Condemnation des Templiers,' &c., par Pierre Du Puy, 2 vols. 8vo, Bruxelles, 1713; and under that of 'Histoire de l'Ordre Militaire des Templiers, avec les Pièces Justificatives,' 4to, Bruxelles, 1751. Other works on the subject are—'Nicolai Gürtleri Historia Templariorum,' 8vo, Amst., 1691, and, with large additions, 1703; 'Christiani Thomasii Dissertatio de Templariorum Equitum Ordine Sublato,' 4to, Halae, 1705; Raynouard, 'Monumens Historiques relatifs à la Condamnation des Templiers,' 8vo, Paris, 1813; Munter, 'Statutenbuch des Ordens der Tempelherren;' Wilike, 'Geschichte des Tempelherrenordens;' and 'The History of the Knights Templars, the Temple Church, and the Temple,' by C. G. Addison, 4to, London, 1842.

TEMPLE (the Latin "Templum") a building set apart for religious uses. What is known of the columnar architecture of the nations of antiquity is derived chiefly from their temples. In the temples of the Egyptians, it may be said to display itself exclusively, and likewise much more extensively than in the temples of the Greeks or Romans, with this further difference as regards the general design and character, that in the Egyptian edifices the columns are placed *internally*, that is, so as to form colonnades along the sides of an enclosed fore-court, and the portal or frontispiece of the temple itself. Of this disposition of the entire plan, with a walled-in cortile or cloister, an example is shown in EGYPTIAN ARCHITECTURE. To that article and the articles GREEK ARCHITECTURE and ROMAN ARCHITECTURE we refer for other particulars relative to Egyptian temples and some of the characteristic differences between them and those of the Greeks and Romans; and to NINEVEH, ARCHITECTURE OF, for notices of the temple-palaces of the Assyrians; and proceed to give in this place some further particulars respecting the temples of Greece and Rome.

Instead of being composed of a variety of parts grouped and combined together, Grecian temples consist only of a simple parallelogram, a *cella*, or body of the temple itself, either *in antis*, or else *peripteral*, that is, entirely surrounded with an external colonnade; for to these two distinctions may be reduced all those subordinate ones for which separate technical terms have been invented: but whatever be their technical designation the general shape and outline still remains a simple unbroken parallelogram, either with or without external colonnades along its sides. Still simple as are the plans of Grecian temples, there are many terms required to express their varieties in regard to the application of columns, besides those denoting the number of columns in front, that is, beneath the pediment. Thus, if there were columns only in front, the building was termed *prostyle;* if at each end, *amphiprostyle;* if there were also colonnades along the sides, it was said to be *peripteral*, that is, with wings (aisles) or colonnades quite round it. When there were two rows of columns, one behind the other, it was termed *dipteral*. Again, where a range of columns was placed between antæ, forming the extremities of walls at right angles with such colonnade, it was said to be *in antis*. This was generally the case with the pronaos, the vestibule or inner portico behind the columns in front. According to the number of columns in front, porticos are said to be *tetrastyle*, that is, with four columns; *hexastyle*, with six; *octastyle*, with eight; *decastyle*, with ten; and *dodecastyle*, with twelve, the greatest number that can very well be brought beneath a pediment; and even of these two last the examples are exceedingly rare. If instead of columns at the angles there were antæ, then the number of columns alone was reckoned as before, and would denominate what would be equivalent to a portico containing two more: thus a *distyle in antis*, that is, two columns between two antæ, would be equal to a tetrastyle, as in both there would be three intercolumns; a *tetrastyle in antis* would be equal to a hexastyle, and so on. When the cella was without a roof, and in part, at least, open to the sky, the temple was termed *hypæthral*.

The following diagrams will render these terms more intelligible, and at the same time serve as examples of the different forms of plan as regards *columniation*, or the arrangement of the columns.

Though so exceedingly small as to show little more than the position of the columns, without any regard to exactness in other respects, these slight diagrams will both serve to render evident many circumstances that cannot else be fully explained, and also to exemplify the respective denominations of temples and porticos according to the number of columns in front. The one "in antis" is a *distyle in antis*, there being only two columns between the antæ, or three intercolumns, as in the two tetrastyle examples (prostyle and amphiprostyle); whereas were there four columns between the antæ, it would become *tetrastyle in antis*, and have as many intercolumns as a *hexastyle*, of which last the peripteral figure is an example. The dipteral and pseudo-dipteral are both *octastyles;* and the hypæthral a *decastyle*. This last may also be taken as an example (though an imperfect one) of a *diprostyle*, for it will be seen that if the portico were a mere prostyle, it would project forward two intercolumns from the body of the temple. In this figure the pronaos may also be termed *polystyle*, on account of the great number of columns in successive rows between the side walls enclosing that part of the plan (pronaos), which may be described as a dipteral or double *tetrastyle in antis*, having a distyle in antis behind it, and a *diprostyle decastyle* in front of it.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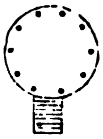
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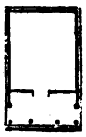
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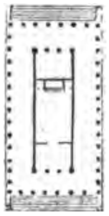
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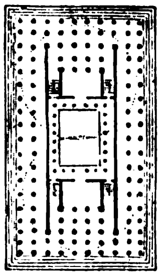
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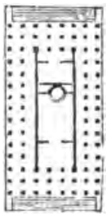
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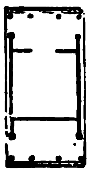
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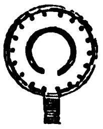
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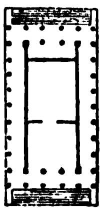

PERIPTERAL

Still there is no variety whatever as to external form, no individual character as to outline or even the general proportions, nothing of combination or of design, as the last term is usually understood; but the difference of effect depended altogether upon the actual dimensions of the structures, upon material and execution, upon circumstances of detail and finish, and on the degree and particular kind of decoration in regard to sculpture and polychromic embellishment. The only instance of combination and grouping is that afforded by the Erechtheion, or triple temple on the Acropolis at Athens, which has two distinct porticos, namely, an Ionic hexastyle monoprostyle at its east end, and a tetrastyle diprostyle of the same order on its north side, and upon a lower level; besides which there is a smaller attached or projecting structure at the south-west angle, forming a tetrastyle diprostyle arrangement of caryatic figures, raised upon a screen-wall or podium. In this combination no regard has been paid to symmetry; for which reason however it is the more striking, as forming a decided contrast to the unvaried and even monotonous uniformity pervading the temple-architecture of the Greeks. It is almost the only Grecian structure that can be said to be as much distinguished by picturesqueness as by elegance of architectural detail. This edifice moreover affords almost the only instance in the Grecian style of distinct porticos or prostyles projecting from a building [PORTICO], other porticos being either in *antis*, so as to be *recessed* within the main walls forming the sides of the edifice; or are only the end or ends of the colonnades continued throughout the whole exterior: consequently in neither case does such portico show itself as an actual prostyle. The only other known examples of Greek prostyles are the two small Ionic temples at Athens, that on the banks of the Ilissus, called the temple of Panops; and that dedicated to Nike Apteros, or Wingless Victory. Both these were amphiprostyle, and not *in antis*, consequently had a projecting portico at each end; and in both the porticos were tetrastyle. Of the former nothing now remains, but it is well known from

Stuart's delineations, and the order itself—of plain and bold but elegant character—has been adopted as the type of most of our modern Grecian Ionic. Though amphiprostyle, the porticos were not exactly similar in plan; for while the one was a mere monoprostyle, that forming the entrance end was also deeply recessed within the main walls, after the manner of a portico in antis without columns. The other temple, that of Nike Apteros, was a very small structure, a mere votive chapel, close by the west front of the Propylæa of the Acropolis, with its hinder portico facing the south wing of that edifice, but turned obliquely from it. For although they carried regularity almost to excess, the Greeks seem to have paid no regard to it whatever in disposing buildings relatively to each other, for there is a similar and apparently intentional want of parallelism between the Parthenon and Erechtheion on the Acropolis itself; nor are either of them in a line with the Propylæa, or equidistant from such line or axis.

This inattention to uniformity of arrangement, where different buildings are brought together on one general plan, shows a striking difference of taste in that respect between the Egyptians and the Greeks. The temples of the Egyptians consist of various architectural parts subordinate to the principal structure, but combining with that and with each other to form a whole; which scheme was sometimes further extended by an architectural avenue of sphinxes in front of the buildings. The Greeks, on the contrary, certainly did not attempt to imitate or rival the Egyptians in the extent and complex arrangement of their temples, though there can be little doubt that they were originally indebted to them for much of their architectural knowledge. Their temples were almost invariably single structures, not only detached from but altogether unconnected with adjacent ones, instead of forming with them a symmetrically arranged assemblage or group. It seems however to have been in some degree the practice with the Greeks as well as with the Romans to erect several temples in the immediate neighbourhood of each other, and in a particular district of a city, as was the case in the Forum and Capitol at Rome, where temple succeeded to temple almost uninterruptedly; and the ruins of Pæstum, Agrigentum, Selinus, and other places show a somewhat similar concentration of sacred edifices about the same spot. Temples were frequently surrounded by a sacred grove or plantation of trees, *temenos*, or else placed within an enclosure, *peribolos*, formed either by mere walls or by colonnades, but there are scarcely any examples of the kind now remaining; and they are chiefly Roman works, namely, the temples at Baalbec and Palmyra. Similarly enclosed and standing in the centre of a peribolos or piazza (therefore very different in plan from an Egyptian temple preceded by a fore-court), were the temples of Jupiter and Juno, Venus and Roma, at Rome [ROMAN ARCHITECTURE, col. 145]; that of Jupiter Olympius at Athens, a work completed in the time of Hadrian; and also, among Græco-Asiatic examples, the temples Athena Polias at Priene, and Apollo Didymæus at Miletus.

Similar as it is upon the whole to that of the Greeks, the temple-architecture of the Romans differs from it in many other circumstances besides those of style; which latter was, with very few exceptions, Corinthian—the national style of the Romans, as the Doric was of Greece and its Italian colonies. One leading distinction in regard to general arrangement is, that Roman plans were hardly ever *in antis*, and not often *peripteral*, but generally prostyle. with the portico projecting out from the *cella*, or body of the structure, three or more intercolumns, so as to be *triprostyle*, &c. [PORTICO.] Such façade was generally further distinguished by having a flight of steps enclosed within pedestals at its ends, which were continued as a podium or moulded basement along the sides of the edifice; whereas the Greeks raised the temples only three steps or so above the ground, and carried those gradini quite round the structure, wherefore each elevation or side of their peripteral temples was uniform in design, having no other variety than that produced by greater extent and number of columns in one direction, and by the pediments at the extremities. The Romans certainly evinced greater taste for both contrast and picturesque combination than the Greeks, although decidedly inferior to them in beauty of detail and finish of execution. In order to give greater dignity to the whole temple or to the principal structure in an architectural group, they elevated it upon not a mere basement or substructure with an ascent in front or at both ends, but upon a spreading-out platform, constituting a terrace on every side. They appear to have occasionally formed a succession of terraces of flights of steps, leading up to if not continued on every side of the building. The celebrated Temple of Fortune at Præneste, usually supposed to have been originally founded by Sulla, was a very remarkable example of the kind. Very little now remains of it, except the terraces themselves; neither have we any account of the architecture, but besides the principal edifice or temple there were several subordinate ones, on the different platforms.

Circular and polygonal plans for temples are peculiar to the Romans, and occasion a diversity of character not to be met with in those of the Greeks. Besides the two simplest forms, the monopteral and peripteral, which have been shown above, there were other varieties and combinations. For a notice of some of them we refer to ROMAN ARCHITECTURE.

Instead of entering into formal descriptions of particular temples, we subjoin a synopsis with accompanying remarks. Some of the

TABLE OF SOME OF THE PRINCIPAL GREEK AND ROMAN TEMPLES.

Athens	Theseion	Doric	Hexastyle, peripteral, with 12 intercolumns on sides, 46 × 105 feet.
„	Parthenon	Doric	Octastyle, peripteral, hypæthral, 100 × 228 feet; Ictinus and Callicrates, architects. [ELGIN MARBLES.]
„	Propylæa	Doric	Hexastyle on both fronts, with wings of a smaller order, at right angles to west front. Mnesicles, architect, 437–432 B.C.
„	Erectheion	Ionic	Hexastyle, prostyle at east end, with a tetrastyle, diprostyle on north side.
„	Panops	Ionic	Tetrastyle, amphiprostyle. A well-known example, though no longer extant, having been destroyed by the Turks since Stuart's time.
„	Nike Apteros	Ionic	Tetrastyle, amphiprostyle. Recently rebuilt.
„	Jupiter Olympius	Corinthian	Decastyle, peripteral, columns 60 feet high, 96 × 259 feet. Enclosed by a peribolus. A Roman work originally begun in the time of Pisistratus, continued by Antiochus Epiphanes, and completed by Hadrian.
Eleusis	Demeter	Doric	A square building of about 180 feet on each side, with a dodecastyle colonnade forming the west front. This temple begun by Ictinus; colonnade added by Philo, architect, about 315 B.C.
„	Propylæon	Doric	Hexastyle on both fronts, with inner Ionic order as at Athens, 50 × 60 feet. A second and smaller propylæon within the peribolos, distyle in antis. See 'Unedited Antiquities of Attica.' None of these buildings now remain.
Thoricus		Doric	Eptastyle, peripteral, or with seven columns at each end, and fourteen on each side. No cella remaining; but supposed to have been a double temple, with a passage through the centre, from the sides, dividing the cella into two.
Rhamnus	Nemesis	Doric	Hexastyle, peripteral, 11 intercolumns on sides, 33 × 70 feet.
„	Themis, or lesser Temple of Nemesis.	Doric	Distyle in antis.
Ægina	Athene	Doric	Hexastyle, peripteral, hypæthral, 41 × 90 feet. [ÆGINETAN MARBLES.]
Olympia	Zeus Olympius	Doric	Hexastyle, peripteral, hypæthral, 95 × 230 feet. Completed about 435 B.C. Libon, architect.
Bassæ	Apollo Epicurius	Doric	Hexastyle, peripteral, hypæthral, 47 × 125 feet. Date about 430 B.C. Ictinus, architect. In interior, Ionic columns.
Tegea	Athene Alea	Ionic	Peripteral, hypæthral. Doric internally; with upper Corinthian order. Scopas, architect.
Nemea	Zeus	Doric	Hexastyle, peripteral.

MAGNA-GRÆCIA AND SICILY.

Pæstum	Poseidon	Doric	Hexastyle, peripteral, hypæthral, 79 × 195 feet.
„	Demeter	Doric	Hexastyle, peripteral, 47 × 107 feet.
Agrigentum	Zeus Olympius	Doric	Apteral, or with engaged columns, eptastyle, 182 × 369 feet. Wilkins, in his restoration of it, makes this temple hexastyle amphiprostyle.
„	Hera	Doric	Hexastyle, peripteral, 57 × 124 feet.
„	Concord	Doric	Hexastyle, peripteral, 81 × 93 feet. Deep pronaos and opisthodomus.
Segeste	„	Doric	Hexastyle, peripteral, 76 × 190 feet. All the external columns (unfluted) standing, but no remains of cella.
Selinus	Great Temple	Doric	Octastyle, dipteral, 160 × 330 feet. There are remains of five other temples, two of which appear to have been hexastyle peripteral.
Syracuse	Athene	Doric	Hexastyle, 13 intercolumns on sides: now converted into a church with a modern Italian Corinthian façade.

Asiatic Greek.

Ephesus	Artemis	Ionic	Decastyle, dipteral, hypæthral, ; columns 60 feet high ; one of the largest Grecian temples, being 220 × 425 feet. Ctesiphon and Metagenes, architects. Date about 340 B.C.
Miletus	Apollo Didymæus	Ionic	Decastyle, dipteral, hypæthral, 164 × 303 feet. Columns 9½ diameters. Pæonius, architect. A peribolos.
Magnesia	Artemis	Ionic	Octastyle, pseudo-dipteral, 106 × 198 feet. Hermogenes, architect.
Priene	Athene Polias	Ionic	Hexastyle, peripteral, 64 × 116 feet. Pytheas, architect, about 340 B.C. The order the best example of Asiatic Ionic. This temple had a peribolos and propylæon ; the latter tetrastyle, with two rows of square pillars within.
Teos	Dionysos	Ionic	Hexastyle, peripteral. Hermogenes, architect ; about the time of Alexander the Great.
Samos	Hera	Ionic	Decastyle, dipteral, 189 × 346 feet.

Roman.

Rome	Concord	Ionic	Hexastyle. Appears to have been a diprostyle, but nothing of the cella remains.
„	Fortuna Virilis	Ionic	Tetrastyle, diprostyle, cella pseudo-peripteral, about 24 × 44 feet.
„	Jupiter and Juno	Corinthian	Two separate temples, alongside each other, in centre of a colonnaded peribolos. Similar in dimensions, but the one octastyle, peripteral ; the other octastyle, diprostyle. Erected by Metellus Macedonicus, about 140 B.C. No remains ; but the authority is the ancient plan of Rome in the capitol.
„	Jupiter Stator	Corinthian	Supposed to have been octastyle, peripteral. The celebrated 'Three Columns,' in the Forum, are all that now remain of this very fine example.
„	Jupiter Tonans	Corinthian	Octastyle, dipteral, 92 × 115 feet. Columns 47 feet high.
„	Mars Ultor	Corinthian	Of this temple, sometimes called that of Nerva, only three columns remain ; but it is said to have been octastyle, peripteral.
„	Venus and Roma	Corinthian	Decastyle, pseudo-peripteral, enclosed within a peribolos formed by double colonnades of a lesser order.
„	Antoninus and Faustina	Corinthian	Hexastyle, triprostyle, 33 × 55 feet.
„	Pantheon	Corinthian	An octastyle, triprostyle, attached to a rotunda.
„	Vesta	Corinthian	A circular peripteral of 20 columns.
Tivoli	Vesta, or the Sibyl	Corinthian	A circular peripteral of 18 columns around cella. The order a very peculiar and fine example.
Præneste	Fortuna		No remains of this celebrated temple itself, but merely of the series of terraces and flights of steps on which it was elevated.
Pompeii	Jupiter	Corinthian	Hexastyle, tetraprostyle, about 50 × 110 feet.
Nismes	Maison Carrée, or Temple of Caius and Lucius	Corinthian	Hexastyle, triprostyle ; order continued along the cella, making it a pseudo-peripteral, 38 × 77 feet.
Baalbec	Great Temple	Corinthian	Decastyle, peripteral, 160 × 290 feet.
„	Lesser Temple	Corinthian	Octastyle, peripteral, 118 × 225 feet.
Palmyra	Helios, or the Sun	Corinthian	Octastyle, peripteral, 95 × 180 feet. Enclosed within a peribolus about 740 feet square, formed by an outer wall and two ranges of Corinthian columns, making a double colonnade.

measurements and other particulars stated in it may not exactly accord with other accounts of the respective structures; for so great is frequently the discrepancy between different authorities, whether writers or delineators and restorers, that it is impossible to obtain complete accuracy.

The above table might be rendered more copious and greatly extended; and it might also have been differently arranged in several ways, each of which would have had something to recommend it, according to the purpose for which it may happen to be consulted. Chronological order, for instance, if the respective dates could be ascertained with tolerable accuracy, may be considered preferable by some persons; or the buildings might have been classified according to the number of columns in front, and as being *in antis*, *prostyle*, *peripteral*, &c.; or else according to their relative size and dimensions. In fact a separate table is required for each mode of classification and arrangement; but as that could not be done, we have adopted what we consider the most satisfactory upon the whole. We may however render it in some measure more complete by here pointing out that the *decastyle* examples mentioned in it are the Temple of Jupiter, Athens; Artemis, Ephesus; Apollo, Miletus; Hera, Samos; Venus and Roma, Rome; and the great temple at Baalbec. As regards dimensions and relative size, the following are the largest structures, namely:—

	Width of Front.	Length.
Ephesus	220 feet	425 feet
Agrigentum, Great Temple	182 „	369 „
Selinus, Great Temple	160 „	330 „
Venus and Roma	116 „	350 „
Athens, Parthenon	100 „	228 „
Temple of Jupiter	96 „	259 „

By way of affording a standard of comparison, we add the dimensions of St. Paul's, London, and La Madeleine, at Paris, namely: the former, 180 by 500; the other 138 by 328 feet.

TEMPLE, SOLOMON'S. For 447 years after the Hebrews had entered the land of Canaan they continued to worship at the tabernacle which had been framed for their use in the Wilderness. [Tabernacle.] The incongruity of a settled people having only a tent for the celebration of their splendid ritual service first occurred to the mind of David. It appeared unseemly to him that the Ark of God should still "dwell between curtains," while he abode himself in "a house of cedar," and he therefore proposed to build a temple in which the worship of God might be more becomingly conducted (1 Chron., xvii. 1). The prophet Nathan was however commissioned to inform him that having been engaged in constant warfare, and shed much human blood, he could not be allowed to execute the design he had formed, which was to be reserved for the peaceful reign of his son Solomon. This undertaking was however a principal subject of David's thought and care during the remainder of his reign; and to it he appropriated a large proportion of the immense treasure which his many victories produced. He may be said to have provided all, or nearly all, the materials before his death; consisting of large but variously estimated quantities of gold and silver, brass and iron, stone and timber. He also secured the services of skilful mechanics and artificers for every branch of the work, and furnished the design, plan, and site of the building; so that more of the credit of this work seems due to David than to Solomon (1 Chron., xxi.; xxii.; xxviii. 11-19).

The foundation of the Temple was laid in B.C. 1012, being the fourth year of Solomon's reign; and in seven years and a half it was completed. During this time 183,600 persons were employed on the work. Of Jews there were 30,000 serving by rotation of 10,000 monthly; and of Canaanites there were 153,600, of whom 70,000 were labourers, 80,000 hewers of wood and stone, and 3600 overseers of the others. To save the labour of carriage, the parts were all prepared for use at a distance from the site of the building, and when they were brought together, the structure was reared without the sound of hammers, axes, or tools of iron (1 Kings, vi. 7).

The site of Solomon's Temple was the summit of Mount Moriah, one of the eminences on which Jerusalem stood. This eminence rose to no great height within the city, but was high and steep above the valley of the Kedron, which it overlooked. It faced the Mount of Olives. The Mosque of Omar now occupies the same site; and the imposing figure which it makes in every view of Jerusalem shows that a more advantageous situation could not have been chosen. The top of the hill was levelled, and the sides banked up to afford a sufficient area. This area was divided into two (but in Herod's temple three) courts, in the outermost of which stood the people. It was separated by a low wall (or, as some think, by a latticed fence or trellis) from the inner court, called the Court of the Priests, in which was the great altar of burnt offerings, and where the priests and Levites officiated in view of the people, and in front of the holy house, or proper temple. The proper temple, as previously indicated, was an oblong building. It was 70 cubits in length, 20 in width, and 30 in height: this last was however only the elevation of the house or holy place, for the innermost sanctuary was but 20 cubits high (1 Kings, vi. 20); and although the porch (pronaos) is said, in 1 Chron., iii. 4, to have been 120 cubits high, or four times the height of the main building, the numbers in that text are now generally admitted to be corrupted: 20 cubits, which we find in the ancient versions, is probably the true number; being the same height as the sanctuary. The porch covered the breadth of the building 20 cubits, and was 10 cubits deep: the holy place was 40 cubits long by 20 wide; the sanctuary was a perfect square of 20 cubits. The building fronted the east. Along the north and south sides, and the west end of the structure, was an upper story, or gallery of wood, and certain buildings called "side chambers," in three stories, each five cubits high. This made 15 cubits of total elevation, which was not more than half the height of the main building, in whose walls, above, there was therefore room for the splayed windows which gave light to the temple.

The sacred utensils were of the same description and occupied the same relative position as in the tabernacle. but some of them were larger, as the altar, candlestick, &c., in proportion to the more extensive establishment to which they belonged. The principal of the new utensils was the great brazen laver for ablutions, which rested on the backs of twelve oxen of the same metal.

The inner sanctuary was separated from the holy place by a rich curtain or veil. The whole of the interior was wainscoted with cedar, carved with figures of cherubim, palm-trees, and flowers, and then overlaid with the finest gold. The doors were also covered with gold: all the utensils in the house were of that metal; and even the floor appears to have been overlaid with gold (1 Kings, vi. 30). It is this lavish expenditure of precious metal upon the building, and the elaborate workmanship bestowed upon it, which, rather than its architectural effect, accounts for the reports of its surpassing magnificence, and for the immense wealth consumed in its erection. The popular impression concerning it, however, being based rather upon the exaggerated statements of Josephus than upon the more sober accounts in Scripture, does, no doubt, greatly exceed the truth. More might be said of its richness than of its grandeur. Its wealth is indeed attested by the spoliations of successive kings and conquerors; and it may be well to remember that this was not, as in other nations, one of many temples, but was the sole temple of the whole nation, and in the production of which the whole nation could therefore concentrate its resources.

The Temple of Solomon retained its pristine splendour only for forty years, when its treasures were plundered by Shishak, king of Egypt. After undergoing various other profanations and pillages, it was finally destroyed by the Chaldæans under Nebuchadnezzar, B.C. 588, after having stood 417 years. After the Captivity, the temple was rebuilt, on the same plan, and on a more extensive scale, but with greatly diminished splendour. This temple stood until some years before the birth of Christ, when Herod the Great, to propitiate his subjects, whom most of the measures of his reign had tended to exasperate, undertook to rebuild it on a larger scale and with greater magnificence. In nine years, during which 80,000 workmen were constantly employed, he accomplished his original design; and produced a fabric, which, while the same in its essential characteristics, much supassed the Temple of Solomon in extent and architecture, although the precious metal may have been less lavishly displayed in the interior decorations. Many years after, the Jews kept workmen employed in emballishing the pile, and in the erection of additional buildings (John, ii. 20). In A.D. 64, nothing remained to be done; but six years later (A.D. 70) the temple and city were involved in one common ruin.

TENACITY (from the Latin *tenacitas*, "the power of holding"), a property of material bodies by which their parts resist an effort to force them asunder.

This property is the result of the corpuscular forces acting within the insensible spaces supposed to exist between the particles of bodies; it is consequently different in different materials, and in the same material it varies with the state of the body with respect to temperature and other circumstances.

Those corpuscular forces consist of attractions which vary according to unknown laws with the distances of the particles from one another, and even at certain distances they become repulsions [ATTRACTION]; but in all bodies except the elastic fluids, the combined actions of all the particles produce that coherence which constitutes the tenacity of the masses. In those fluids the particles have no coherence, and when the pressures to which they are subject are removed, those particles immediately separate from each other with forces depending, probably, upon the quantity of caloric with which they are combined. In non-elastic fluids and in solids, tenacity exists, but in very different degrees; its force depending upon differences in the intensity of the attracting powers between the particles, upon differences in the distances of the particles themselves, upon the action of the caloric, and, in some cases, upon variations in the pressure of the atmosphere.

The molecules of liquids adhere to one another, and generally to those of solid bodies, by attractive forces which decrease very rapidly; and, at insensible distances from the supposed places of contact, the adhesion entirely disappears [CAPILLARY ATTRACTION]: the real tenacity of the molecules being, as Dr. Young observes, equal to the excess of their mutual attractions above the forces of repulsion arising from the actions of the calorific particles. It is on account of the small distance to which the attractions of the fluid molecules extend, and to the freedom with which the particles move on one another, that fluids appear to have so little tenacity; but from the weight of water-support in glass tubes, Dr. Robison has estimated that the mutual attractions of the particles of water on a surface equal to one square inch must far exceed 190 pounds.

Grains of dust or sand, while dry, have no power of adhering together, probably because their forms do not permit a sufficient number of points on their surfaces to be brought within the distance at which corpuscular attractions take place; but, if slightly wetted, the mutual attractions between the dust and the liquid produce a certain degree of tenacity. This is very sensible in clay moistened with water; for, being then drawn into the form of a rod, it is capable of bearing a small weight suspended from it. Tenacity exists in various degrees in viscid fluids, as oil, gum dissolved in water, &c. Sealing-wax and glass also, when heated, lose their brittleness, and acquire *plasticity*, whereby they become capable of being moulded into any form, while their particles retain a considerable degree of adhesive power.

The tenacity of solids constitutes, in part, the subject of the power of bodies to resist strains; and under MATERIALS, STRENGTH OF, will be found a table of the weights which would overcome the force of cohesion in rods immoveably fixed at one end and pulled in the direction of their length. Those weights may be considered as the measures of tenacity in the different kinds of material; and it may be added that, from a mean of several experiments made by Telford on the tenacity of forged iron, the breaking strength, when reduced to that which it would be if the area of a transverse section of the bars had been one square inch, is 29¼ tons. The bars were cylinders or parallelopipeds varying in length from 1 foot 5 inches to 2 feet 3 inches, and in area of section from 0·56 to 3·14 square inches: they stretched in length from two inches to four inches before they broke. Telford found, also, that a bar of cast-steel bore, suspended from it, 27·92 tons, a bar of blistered steel 17·27 tons, and of cast-iron (Welsh pig) 7·26 tons; the area of the section in all being one square inch. Tenacity in solid bodies varies greatly with their temperature. Coulomb took a piece of copper-wire, which, when cool, carried 22 lbs. suspended from it; and, upon bringing it to a white heat, it would scarcely bear 12 lbs.

Though, when a piece of metal is fractured, the parts will not by simple adjunction adhere together, yet, in some cases, by hammering them upon one another, so many points on their surfaces may be brought within the limits to which the force of cohesion extends, that they will acquire a tenacity equal to that which the metal had in its natural state.

The tenacity of wood is much greater in the direction of the length of its fibres than in the transverse direction, the fibres being united by a substance having little cohesive power. Few experiments have been made on the tenacity of wood perpendicularly to its grain, as it is called; and from those of Mr. Emerson it appears to vary from one-tenth to one-seventh of the tenacity in the other direction. When a strain takes place in the direction of the fibres, they become disengaged from one another, and thus lose the strength which arises from their lateral cohesion. They then become subject to separate strains; the weaker ones are first ruptured, and at length all give way, leaving an irregular surface of fracture. [ADHESION.]

With respect to metals, the processes of forging and wire-drawing increase their tenacity in the longitudinal direction; the augmentation of friction and lateral cohesion, arising from the particles being forced together in the transverse direction, more than compensates for the diminution of the attraction which may result from the particles being forced or drawn farther asunder longitudinally. Copper and iron have their tenacity more than doubled, while gold, silver, brass, and lead have it more than tripled by those metals being drawn into wire.

Mixed metals have, in general, greater tenacity than those which are simple: the tenacity varies with the different proportions in which the metals are mixed; and the proportions which produce the greatest strength are different in different metals. The only experiments on this subject with which we are acquainted are those of Muschenbroek; and from these we find that a compound of which ⅚ were gold and ⅙ copper, had a tenacity, or force of cohesion, more than double that of the gold or copper alone: brass, composed of copper and zinc, had a tenacity more than double that of the copper, and nearly twenty times as great as that of the zinc: a metal of which ¾ were block-tin and ¼ lead, had a strength more than double that of the tin; and a mixture of which ⅚ were lead and ⅙ zinc, had a tenacity nearly double that of the zinc, and nearly five times as great as that of the lead alone.

TENAILLE, in Fortification, is a rampart raised in the main ditch, immediately in front of the curtain between two bastions; and in its most simple form, it consists of two faces coinciding in direction with the faces of the bastions, and, consequently, forming with each other a re-entering angle. Generally, however, it consists of three faces, of which two have the directions just mentioned, and the third forms a curtain which is parallel to that of the enceinte. See P, *fig.* 1, BASTION, and P (in the plan), FORTIFICATION.

This work was originally proposed by Vauban, in order to serve the purpose, in part, of a fausse-braye [FAUSSE-BRAYE], since the fires of musketry on its faces may be employed, in conjunction with those of artillery and musketry on the flanks of the bastions, to oppose the passage of the enemy across the main ditch when about to mount a breach in the ramparts of the place.

The relief of the tenaille, or the elevation of its crest above the bottom of the ditch, is determined consistently with the intention of thus defending the main ditch; and in order that the defenders of the tenaille may not be injured by the shot fired over their heads, from the flanks of the bastions, it is usual to make the crest of that work coincide with a horizontal plane passing three or four feet below the point where a line of fire from one of those flanks would cut a vertical plane, bisecting the angle of the tenaille or its curtain. The height thus determined will allow the parapet of the work to be elevated from two to four feet above the terreplein of the ravelin in its front;

and, consequently, from the curtain of the tenaille a grazing fire of musketry might be employed to protect the interior of the ravelin, or of its reduit, if there is one, should the defenders of either of those works abandon it (in consequence of an assault being made) before the enemy has time to cover himself in it by a lodgment: that fire will also contribute powerfully to prevent the enemy from attempting to enter the ravelin by its gorge.

Vauban, at first, gave to his tenailles short flanks nearly parallel to those of the bastions, but he soon abandoned that construction, perceiving that though the defenders might thus fire correctly along the main ditch, yet the parapets of those flanks were liable to be destroyed by the fire from the enemy's counter-batteries [H, *fig.* 1, Bastion], and they were enfiladed from the rampart of the ravelin (Q), or from the glacis of the places of arms (L).

Besides affording additional fires for the defence of the main ditch, the tenaille serves to cover, in part, the revetment of the curtain in its rear, and prevent it from being breached by fire from any lodgments of the enemy on the glacis. Its parapet serves also to mask the postern in the curtain of the enceinte, which would otherwise be so much exposed to the fires from the counter-batteries, that the defenders might be unable to communicate through it with the outworks. On this account the breadth of the ditch between the curtain of the tenaille and that of the enceinte is made such only as to allow the parapet of the former, with the relief determined as above-mentioned, to conceal the postern from the view of the enemy on the glacis. This ditch is advantageous in preventing the defenders of the tenaille from being injured by the splinters which may be detached from the flanks and curtain behind it; and, when dry, it serves to cover bodies of troops which may issue from thence and attack the enemy while crossing the main ditch, previously to making an assault. If the main ditch contains water, the tenaille serves to cover the boats and rafts by which the defenders of the enceinte communicate with the outworks.

The tenaille has been considerably improved by Bousmard, who, returning, in one respect, to the original idea of Vauban, has given flanks to the work in order that the main ditch may be directly defended by them. These flanks are raised high enough to cover the revetments of the flanks of the bastions, while their upper surfaces may be grazed by a fire of artillery from thence; and, instead of being formed with open terrepleins, and parapets for musketry, as usual, each flank of the tenaille is provided with casemates, or vaults, for four pieces of artillery which are placed nearly on a level with the terreplein of the covered-way. These guns are consequently capable of being directed against the counter-batteries (H) of the enemy, as well as of defending the foot of a breach in the face of the bastion.

This construction was adopted by Chasseloup de Laubat in the tenailles of the detached works which he executed about Alessandria, in Italy, when Napoleon (after the battle of Marengo) proposed to make that city the base of his operations beyond the Alps. But, in order to avoid the mischief which results from a fire directed against casemates (the shot in striking the cheeks or sides of the embrazures detaching from them splinters, which being driven into the vault do more injury to the defenders than the shot itself), this engineer raised before each flank of the tenaille a mass of earth which was reveted with brickwork, and perforated in such directions that, in defending the ditch, the shot from the casemates could be fired through the apertures, while the mass served as a mask which would prevent the enemy from seeing the embrazures in the flanks of the tenaille.

Any work belonging either to permanent or field fortification, which, on the plan, consists of a succession of lines forming salient and re-entering angles alternately, is said to be *à tenaille*.

TENAILLON, or Great Tenaille, in Fortification, is a species of exterior work which has been occasionally constructed before the faces of a small ravelin, with a view of increasing the strength of the latter, procuring additional space beyond the ditch, or covering the shoulders of the bastions. They were invented by Vauban, who, however, very seldom constructed them; and subsequent engineers have generally considered them as inferior in defensive qualities to a counterguard [Q Q, Fortification, *fig.*, cols. 171-172,] placed over the faces and salient angle of the ravelin.

The form and position of a tenaillon may be understood, Y being supposed to represent a small ravelin, if beyond the ditch of the latter the ramparts of the right and left faces be produced till each of them meets a rampart nearly perpendicular to the face of the bastion and extending to the place of meeting from the counterscarp of the main ditch at a point opposite the middle of that face. The works thus formed, one over each face of the ravelin Y, constitute a tenaillon; before each line of rampart is a ditch, and part of the general covered-way, the main ditch and that of the ravelin being in the rear. The two faces which are beyond the salient angle of the ravelin would, if produced towards the latter, form with each other a re-entering angle, whose vertex would coincide with that of the said angle.

The objections to tenaillons are, that the besieger would experience little difficulty in establishing a lodgment on that part of the covered-way or glacis which is immediately in front of the salient angle of the ravelin; and in this situation he would be able to breach the faces of the two half-bastions in four places, by fires of artillery directed along the ditches of the ravelin and those on the side faces of the tenaillon. The salient angles of the tenaillon, and of the ravelin which it covers, may be breached at the same time, and, when the ditches are dry, it would be possible to attack and carry the ravelin at the time of making the assaults on the tenaillon: then, the enemy having got possession of the former work, any retrenchments which may have been made in the tenaillon must necessarily be abandoned by the defenders.

The re-entering space between the two faces which are in the prolongation of the faces of the ravelin, and which constitute the head of the tenaillon, is sometimes occupied by a small redout, consisting of two ramparts perpendicular to the faces which have been just mentioned; and thus there may be obtained a good crossing fire for the defence of that part of the covered-way which is concealed by the salient angles of the tenaillons from the defenders of the bastions.

Demi-tenaillons are works placed also on the sides of a ravelin, and consisting of two ramparts which are perpendicular to and nearly opposite the middle of the faces of the bastions and ravelins: these are usually accompanied by counterguards which cover the salient angles of the latter works, and are called *Bonnets*.

TENANCY. [Tenant.]

TENANCY IN COPARCENARY. [Estate.]

TENANT. Tenants, in the more extended legal sense of the word, are of various kinds, distinguished from each other by the nature of their estates; such as tenants in fee simple, in fee tail, for life, for years, at will, and at sufferance. [Estate; Tenure.]

TENANT AND LANDLORD. The word tenant, in the more limited legal sense, which is also the popular sense, is one who holds land under another, to whom he is bound to pay rent, and who is called his landlord. The word Land means not only land itself, but also all things, such as buildings, houses, woods, and water, which may be upon it. Any one who has an estate in land, provided he is also in possession, may let the land to another. Where the letting takes place by an express contract between the parties, the contract is called a Lease, the nature of which is explained generally under Lease.

But the relation of landlord and tenant may be created otherwise than by a formal lease. If one man with the consent of another occupies his land, a contract of letting is assumed to have been made between them, and the occupier becomes tenant at will to the owner. Such tenants are, after payments of rent as in annual tenancies, considered to be upon the same footing as if the lands had been let to them for a year dating from the commencement of their occupation. And at the end of the first year, a second year's tenancy begins, unless six months' notice of the intention to determine the contract has been given by either party to the other, and so on from year to year. The same rule of law applies to cases where a tenant continues to occupy land after the expiration of a lease made by deed; but in this case all the covenants of the expired lease as to payment of rent, repairs, insurance, and the like, are in force unless the lease is cancelled by destroying the seal; and even if there should be a verbal agreement for a different rent, still the old covenants subsist, unless the lease is cancelled. [Deed.]

In every case where the relation of landlord and tenant exists, either by express or by implied contract, certain terms are implied by law to have been agreed upon by the parties as forming part of the contract. It is of course in the power of the parties, where the contract is express, to qualify these terms so implied by the language of the contract itself. But it may be observed that as these terms are comprehensive in their nature, and distinctly understood in law, the interests of parties are often better consulted by leaving them to the general protection afforded by these implied terms than by attempts to define by enumeration in detail the respective rights and duties of the landlord and tenant. The terms implied on the part of the landlord are, that the tenant shall quietly enjoy the premises without let or hindrance from the landlord; on the part of the tenant, that he will pay rent, keep the premises in repair to a certain extent, and use the land, &c. in a fair and husbandlike manner.

When the landlord is himself tenant of the premises to a superior landlord, and neglects to pay his rent, and the occupying tenant is called upon to pay it to the superior landlord, he may do so, and set it off against the rent due from him to his own landlord. If a tenant has covenanted without exception or reservation to pay rent during the term for which the lease has been granted to him, he will be bound to pay it even if the premises should be destroyed by fire or other casualty. If he should have assigned his lease to another and ceased to be in possession, he will still remain liable under his covenant to pay rent.

The rules of law as to the repairs of premises may be determined by the terms of the lease. If they are not determined by the terms of the lease, they are somewhat uncertain and depend on a variety of circumstances, which are laid down in law treatises.

No tenant, in the absence of an agreement to that effect, is bound to rebuild after accidental destruction of the premises by fire. But under a general covenant to repair, and *leave repaired*, the tenant is bound to rebuild even in the case of destruction by fire.

In agricultural tenancies the lease generally determines the mode in which the farm is to be treated. [Lease.] Unless also the lease expressly or impliedly excludes the operation of the custom of the country, the tenant is bound to conform to it. The custom of the country means the general practice employed in neighbouring farms of a similar description, with reference to rotation of crops, keeping up fences, and other like matters. In leases of farms it is often the practice to protect the landlord against certain acts of the tenant, such as ploughing up meadow land, &c., by introducing certain provisions into the lease. These provisions may operate according to the phraseology used, either to assign a penalty or to determine the liquidated damages agreed to be paid for the act done. It is often a matter of great importance and of some nicety to determine under which class the provisions fall. If under the first, the landlord is not entitled to the whole penalty upon the act being done, but he can only recover in an action the amount of the actual damage which has accrued. If under the second, he is entitled to the whole amount of the damages agreed on. A covenant by a tenant not to plough up meadow under a penalty of *5l.* for every acre ploughed, is an instance of the first class: a covenant to pay *5l.* rent for every acre of meadow ploughed up, is of the second class. The right to timber and timber-like trees belongs to the landlord; loppings of pollards and bushes, to the tenant. Different definitions prevail in different counties of timber and timber-like trees, and various customs prevail as to what amount of wood the tenant may be allowed to employ (after the landlord has been called on to select it) for the purposes of the farm. No tenant, unless he employs the land as a nurseryman or gardener, can remove any kind of shrub from the soil. Neither can a tenant remove fixtures, though put down by himself. A fixture is a chattel which is let into the soil, or united to some other which is let in. There are some exceptions to this rule in favour of fixtures used for the purpose of trade or agriculture, or merely ornamental purposes, where the removal will cause little or no damage. (Amos and Ferard, 'On Fixtures.')

The tenant in occupation of the premises is, in the first instance, liable for all taxes and rates of every description due in respect of the premises. The party, therefore, who is authorised to collect them may proceed against the tenant in occupation to recover them. It is generally a matter of agreement between the landlord and tenant that the tenant shall pay all rates and taxes except the land tax; and sometimes it is agreed that the landlord shall pay the sewer rate also. If, however, the landlord has undertaken to pay the tenant the rates and taxes, and fails to do so, the tenant may deduct the amount from his rent, or bring an action to recover it; but this should be done during the current year, and if the tenant allows a considerable time to elapse without claiming a deduction or bringing an action, he will be held to have waived his claim to recover them from the landlord.

Where a fixed rent has been agreed upon, has become due, and is neither paid nor tendered, the landlord, with certain exceptions, can distrain growing crops, any kind of stock, goods, or chattels, upon the premises, or pasturing any common enjoyed in right of the premises, whether such things are the actual property of the tenant or not; and if the rent remains unpaid, he may sell them. It follows from this general rule that a landlord can distrain on the goods of a lodger who occupies under his tenant. [Distress; Rent.]

A tenant ceases to be so if he incurs a forfeiture, which may arise either by a breach by the tenant of one of those conditions which are implied by or attached to the relation of landlord and tenant, as where a tenant disclaims or impugns the title of his landlord by acknowledging, for instance, the right of property to be vested in a stranger, or asserts a claim to it himself, or by a breach of a condition which is expressly introduced into the lease, the breach of which is to be attended with a forfeiture of the tenancy, as a condition to pay rent on a particular day, to cultivate in a particular manner, &c. To this head may be referred provisoes in a lease for re-entry by the landlord on the doing or failure in doing of certain acts by the tenant, such as the commission of waste, the failure to repair, &c. The courts are said to be unfavourable to forfeitures; therefore, when the landlord has notice of an act of forfeiture, or an act which entitles him to re-enter, he must immediately proceed in such a way as to show that he intends to avail himself of his strict legal right. If after the commission of the act he does anything which amounts to a recognition of the tenancy, as by the acceptance of rent subsequently due, he will have waived his right to insist upon the forfeiture.

A yearly tenancy, where no period of notice is agreed on, must be determined by a notice to quit at the expiration of the current year, given six months previously. In the case of lodgings, the time, when less than a year, for which they are taken, will be the time for which a notice is necessary. Thus lodgings taken by the month or week require a month's or week's notice.

The notice to quit need not be in writing, though, from the greater facility of proving it, a written notice is always better. It should distinctly describe the premises, be positive in its announcement of an intention to quit or require possession, be signed by the party giving it, and served personally upon the party to be affected by it.

If a tenant, after having given notice to quit, continues to occupy, he is liable to pay double rent. If he does so, no fresh notice is necessary. If he continues to occupy after the landlord has given him notice, he is liable to pay double value for the premises.

At the expiration of the lease, the tenant is bound to deliver up possession of the premises; but if either by special agreement or by the custom of the country the tenant is entitled to the crops still standing on the land, and which are called away-going crops, he may enter for the purpose of gathering them, and also use the barns and stables for the purpose of threshing them. The in-coming tenant may also enter during the tenancy of the preceding tenant to plough and prepare the land.

If the tenant refuses to deliver the possession of the land, the landlord may bring an action of ejectment. [Rent; Ejectment.]

TENANT AT WILL, AND FROM YEAR TO YEAR. "Tenancy at will," says Littleton, s. 68, "is where lands or tenements are let by one man to another to have and to hold to him at the will of the lessor, by force of which lease the lessee is in possession. In this case the lessee is called tenant at will because he hath no certain or sure estate; for the lessor may put him out at what time it pleaseth him."

An estate at will may arise by implication, as well as by express words. Thus, where a tenant for years continues in possession after the expiration of his term, and pays rent as before, the payment and acceptance of rent constitute a tenancy at will. So, where a man enters under an agreement for a lease or a contract for the purchase of an estate, he must be considered at law as the tenant at will of the person who has the legal title.

Where a mortgagor continues in possession of his land with the consent of the mortgagee, after default in payment of principal and interest at the time stipulated in the mortgage deed, he is tenant at will. So also, where the legal estate is vested in a trustee, the beneficial owner, or *cestuique trust*, if he be in possession, is considered at law as tenant at will under the trustee.

A tenancy at will may be determined either by express declaration of the lessor that the tenant shall hold no longer, which must be made on the land, or notice given of it to the lessee; or by some act of ownership exercised by the landlord inconsistent with the continuance of the estate, such as entering on the land and cutting down trees demised, making a feoffment, or a lease for years to commence immediately. On the part of the tenant, any act of desertion, an assignment of the land to another, or the commission of waste, is a determination of his estate. A lessor determining the tenancy before the rent is due loses the rent; and on the other hand, the lessee who determines it before the rent is due, must notwithstanding pay it up to that time. If either party die, the tenancy, if it be of a house, continues till the next rent-day; and if of land, until the summer profits are received by the tenant or his representatives.

Where a tenancy at will is determined by the lessor, the tenant is entitled to emblements; but not if it be determined by the tenant himself.

The courts are always inclined to construe demises where no certain term is mentioned, not as estates at will, but as tenancies from year to year; and the circumstance of an annual rent being reserved has been considered sufficient to warrant this construction. Where a remainderman receives rent from a tenant under a lease for years which is void as against him, before electing to avoid it, a tenancy from year to year is created. Also where an agreement for a lease for more than three years is made by parol, and is therefore void by the Statute of Frauds, there is a tenancy from year to year regulated by the terms of the agreement.

A tenancy from year to year, when once constituted, is binding not only upon the reversioner, but his assignee, and does not cease upon the death of the tenant, but goes to his executors or administrators. The tenant is entitled to six months' notice to quit, ending at the expiration of the year, and thus a new year is continually added to the term as often as the half year's previous notice is omitted to be given at the proper time.

TENANT FOR LIFE. Tenancy for life of lands or tenements is the possession of a freehold estate or interest, the duration of which is confined to the life or lives of the tenant or some other person or persons.

The estate of the tenant for life is either (1) such as is created by deed or some other legal assurance, or (2) such as arises by operation of law.

(1) An estate for life may be created by lease with livery of seisin, or by any other conveyance at common law which might be employed in conveying the fee, or by a declaration of a use, or by will. The estate so limited may be either to a person for his own life, or it may be given to one for the life of another, or for any number of lives mentioned in the grant. In the last case, the estate is in effect one for the life of the survivor of the persons so named. On the other hand, an estate may be granted for the joint lives of A and B, in which case it is in fact an estate for the life of the person who dies first.

When lands or tenements are conveyed by deed, without any express limitation of the quantity of estate to be taken by the grantee, he takes an estate for life only. This however is the case only when the grantor might lawfully create such an estate; for if he be tenant-in-tail, the conveyance, unless it be a lease within the provisions of the statute 32 Hen. VIII., c. 28, will pass only an estate for the life of the grantor. Before the 1 Vict., c. 26, a devise without words of limitation conferred on the devisee a life estate only; but now by sec. 28 of that act, a devise, though without any words of limitation, passes the fee simple, or the whole of such other estate as the testator had power to dispose of, unless a contrary intimation appear by the will.

Formerly, when lands were given to A for the life of B without any words of limitation, if A, or the person to whom he had assigned his estate, happened to die in the lifetime of B, the estate was considered as a kind of *hereditas jacens*, belonging to whoever first took possession; and the person who did so was called the general occupant. [Occupancy.]

A gift to two persons for their lives is an estate in joint tenancy, and for the life of the survivor, if the parties continue joint tenants; but if the jointure be severed, each has then an estate in the moiety for his own life only.

(2) The estates for life arising by operation of law are, the estate tail after possibility of issue extinct, and the estate by courtesy and the estate in dower.

The estate tail after possibility of issue extinct arises when, by the death of one of the persons from whom the inheritable issue is to proceed, it has become impossible that any person should exist upon whom the estate tail can descend. Thus, if the lands be given to A and the heirs of his body by B, his wife, or to A and B and the heirs of their bodies, and B die without leaving any issue of their two bodies living, A, from being tenant-in-tail special, becomes tenant-in-tail after possibility of issue extinct; which is in effect nothing more than a tenancy for life, with certain peculiar privileges remaining to the tenant out of his former inheritance, the principal of which is the right of committing waste.

As to the nature and incidents of tenancy by the courtesy and tenancy in dower, see COURTESY and DOWER.

Tenants for life are entitled to estovers; that is to say, to an allowance of necessary wood for the repair of houses and fences on the land; but no tenant for life, except tenant-in-tail after possibility of issue extinct, can cut down more timber than is necessary for such purposes, or build new houses, or open mines, without being guilty of waste, unless his estate be, as it may be, made expressly without impeachment of waste. [WASTE.]

A tenant for life is not bound to pay off the principal of incumbrances affecting the inheritance, but he is bound to keep down the interest of all such incumbrances. He may convey or demise his tenement by the same means as a tenant in fee, provided he does not attempt to convey any estate greater than his own.

If he convey by grant, lease for years, bargain and sale, or lease and release, he can pass no interest greater than that which he himself possesses, the conveyance for the excess is merely void, and no forfeiture is incurred. But a conveyance by feoffment, or by any assurance equivalent to a fine or recovery, if purporting to exceed the bounds of the life estate, displaces the estates in remainder and creates a wrongful fee simple. The person entitled to the next estate in remainder or reversion becomes then immediately entitled to enter, thereby restoring all the estates which had been displaced by the tortious conveyance, except that of the tenant for life, which becomes absolutely forfeited.

As to the merger and surrender of estates for life, see MERGER and SURRENDER.

The name tenant for life is also applied to the person to whom, in settlements or wills of personal property, is given an interest for life only in the fund which is the subject of the settlement or will. [SETTLEMENT; WILL.]

TENANT FOR YEARS. [ESTATE; LEASE; TENANT AND LANDLORD.]

TENANT AT SUFFERANCE, says Lord Coke, "is he that at first came in by lawful demise, and after his estate endeth continueth in possession, and wrongfully holdeth over." Thus a tenant *pur autre vie*, continuing in possession after the death of *cestuique vie*, a tenant for years holding after the expiration of his term, and a person who, having been tenant at will, continues in possession after the death of the lessor, are all tenants by sufferance.

As the tenant at sufferance holds only by the laches of the owner, there is no privity of estate between them, and therefore the tenant at sufferance is not capable of taking a release of the inheritance. Tenants at sufferance were not bound to pay any rent; till by the 4 Geo. II., c. 28, § 1, it was enacted that " where any tenant holds over after demand made and notice in writing given for delivering the possession, such persons so holding over shall pay double the yearly value of the lands so detained, for so long a time as the same are detained; to be recovered by action of debt, against the recovering of which penalty there shall be no relief in equity."

TENANT RIGHT. It is good policy in the owners of land to give liberal acknowledgement of the tenant's right to the unexhausted improvements of the land which he has held, if he should be forced to leave it; because this will induce him to cultivate it with energy and liberality. Accordingly in some parts of the country, and especially in Lincolnshire, it is the custom to give the tenant on leaving a proportion of his expenditure during the last few years of his tenancy—varying in amount with the number of years which has elapsed since the expenditure, and the character as to permanence of the improvement. The following table may be taken as describing a not uncommon set of allowances:—

Description of Improvement.	Conditions Annexed.	Rate of Compensation to be Allowed on Quitting.
1. Fine ground bone and half-inch bones	On drained or naturally dry tillage land . .	Two-thirds of the cost of what has been used in the last year of tenancy, and one-third of that used in the year preceding.
2. Bone dust and half-inch bones .	On dry or well-drained pasture or meadow land, the same not being afterwards mown	Seven-eighths of the cost of that used in the last year of tenancy, and diminishing one-eighth every previous year subsequent to the application.
3. Dissolved bones or guano . .	On dry or well-drained land . . .	One-fourth of the cost of that used in the last year of tenancy for turnips and rape.
4. Lime . . .	On dry or well-drained land	Three-fourths of the cost of that used in the last year of tenancy, and one-fourth of that used in the preceding year.
5. Linseed-cake .	Consumed on the farm	Three-fourths of the cost of that used in the last year of tenancy. The manure being carefully preserved in the foldyard.
6. Draining — landlord finding tiles	Provided the drains are not less than 3 feet deep at regular distances, and cut under the superintendence of the landlord or his agents, and are in perfect order at the expiration of tenancy	Four-fifths of the expense of cutting, laying, and filling in the drains made during the last year of tenancy, and diminishing one-fifth for every crop grown on the land since it was drained.
7. Draining—tenant finding tiles . .	Same proviso as above .	Six-sevenths of the cost of those made in the last year of the tenancy, and decreasing one-seventh for every crop grown since it was drained.
8. New buildings or walls — landlord finding materials	Provided the same are done under the direction and approved of by the landlord or his agent, according to plan and specification previously agreed upon	Nine-tenths of the cost of those erected in the last year of the tenancy, and decreasing one-tenth for each year's occupation after erection.
9. Ponds . .	Same proviso as above .	Nine-tenths of the cost of those made or filled up in the last year of the tenancy, and decreasing one-tenth for each year's occupation after completion.
10. New walls or buildings — tenant finding all materials . .	Same proviso as above, tenant keeping and delivering up in good repair . . .	Nineteen-twentieths of the cost of those made in the last year of tenancy, and decreasing one-twentieth for each year's occupation after erection.
11. New fences of hawthorn—landlord finding posts and rails . .	Provided they have been properly protected and cleaned . . .	Nine-tenths of the cost of those made in the last year of tenancy, and decreasing one-tenth for each year's occupation after completion.
12. Clover and grass seeds . . .	Provided proper seeds have been sown in a husbandlike and proper manner, and have not been depastured or trod by stock.	The invoice cost of seeds sown in the last year of tenancy.

The advantage of such a set of allowances to the owner of the land consists in its tendency to produce vigorous and intelligent cultivation; its advantages to the tenantry and labourers are obvious.

Tenant Right is the name for a species of customary estates peculiar to the northern parts of England, in which border services against Scotland were anciently performed before the political union of the countries. Tenant-right estates were holden of the lord of the manor by payment of certain customary rents and the render of the services above mentioned, are descendible from ancestor to heir according to a customary mode differing in some respects from the rule of descent at common law, and were not devisable by will either directly or by means of a will and surrender to the use of the same, though they are now made devisable by 1 Vict., c. 26, s. 3. Although these estates appear to have many incidents which do not properly belong to villeinage tenure or copyhold, not being holden at the will of the lord, or by copy of court roll, and being alienable by deed and admittance thereon, it has been determined that they are not freehold, but that they fall under the same general rules as copyhold estates. (Doe *d.* Reay *v.* Huntington, 4 East, 271.)

TENANT IN FEE-SIMPLE. A tenancy in fee-simple is the greatest estate which a subject can have in land. [TENURE.] The possession of an estate in fee-simple involves a complete power of disposition over the land; and after a grant made in fee-simple the grantor has parted with his whole interest.

The words necessary for transferring an estate in fee simple may be reduced to this form: "I give this land to you and your heirs." (Litt., 1.) The addition of the word "heirs" is absolutely necessary in a deed, and no other expression will serve; for any such words as "I give the land to you;" or "to you for ever;" or "to you in fee-simple," would carry to the grantee nothing more than an estate for life. But words of limitation, such as "heirs," are not now necessary to pass a fee-simple by devise. (1 Vict., c. 26, s. 28.)

Lands in fee-simple in the hands of the heir were subject at common law to the debts of the ancestor due to the crown and to specialty debts. By the 11 Geo. IV. and 1 Wm. IV., c. 47, a complete remedy was given for all kinds of specialty debts, both against the heir and devisee; and by the 3 & 4 Wm. IV., c. 104, estates in fee-simple are made liable in the hands of the heir or devisee for payment of the simple contract debts of the ancestor.

Estates in fee-simple are forfeited to the crown for high treason. (Co. Litt., 390 b.) In cases of petty treason and felony the forfeiture to the crown is only for a year and a day, called the *annus, dies et vastum;* after which time the estate escheats (in cases of petty treason and murder) to the lord. By the 54 Geo. III., c. 145, the forfeiture and escheat consequent upon attainder for felony, except in cases of high treason, petty treason, and murder, are limited to the life-interest of the offender. It would seem that this statute leaves the offender the power of disposing of the estate after his decease. Trust-estates in fee-simple may be forfeited to the crown, but are not liable to escheat.

An estate to a man and his heirs may be given upon conditions or limitations, which are capable of abridging or defeating it. The estate cannot then properly be called a fee-simple; but is, according to the circumstances, a conditional, qualified, or base fee. (Co. Litt., 1 b.)

TENANT-IN-TAIL. The origin and general nature of estates tail have been already described. [Estate; Remainder; Settlement.]

The estate of the tenant-in-tail has some essential characteristics. He has a right to commit waste of all kinds by felling timber, pulling down houses, opening mines, and doing other like acts; and this right of the tenant-in-tail cannot in any manner be restrained. The tenant-in-tail is also entitled to the custody of the title-deeds, which the Court of Chancery will order to be delivered up to him. He is not bound to pay off incumbrances affecting the fee of the estate, as he has only a particular interest, and not the entire property in the land; and it seems that he is not in general even bound to keep down the interest on such incumbrances; though if he do pay off such incumbrances, it will in general be presumed to have been done in exoneration of the estate.

By the statute *De Donis* the tenant-in-tail was restrained from alienating his estate in any manner for a longer period than his own life, that is to say, the estate of the alienee, though not *ipso facto* determined by the death of the tenant-in-tail, became thereupon defeasible by his issue or the remainder-man or reversioner.

If the tenant-in-tail conveyed his estate by lease and release, covenant to stand seised, or bargain and sale and grant, the right of entry of the issue and remainder-men was not affected by the conveyance. But a feoffment or fine made or levied by the tenant-in-tail in possession by virtue of the entail, caused what was called a discontinuance of the estate tail, whereby the issue and the persons in remainder and reversion lost their rights of entry and were driven to their action. A fine duly levied with proclamations was an absolute bar to the issue, though not to the remainder-men, creating what was called a base fee; and by means of a common recovery duly suffered, the tenant-in-tail might bar his issue and all the remainders over, and make an absolute conveyance of the estate. [Recovery.]

By the 3 & 4 Wm. IV., c. 74, fines and recoveries were abolished; and by the Statute of Limitations (3 & 4 Wm. IV., c. 27) it was enacted "that no discontinuance or warranty should thereafter defeat any right of entry or action for the recovery of land. It seems therefore that no discontinuance, properly so called, can now be produced by any mode of conveyance, for, whatever may be the form of discontinuance, the last-mentioned statute takes away its effect. [Fine; Recovery.]

In accordance with the principle which prevented a tenant-in-tail from alienating his estate for more than his own lifetime, leases by tenants-in-tail might be avoided after their death by the issue in tail. But by the 32 Hen. VIII., c. 28, tenants-in-tail were enabled to make leases for three lives or twenty-one years, which should bind their issue, though not the persons in remainder or the reversioner.

The estate of the tenant-in-tail is not subject to any of the debts or incumbrances of his ancestor, except debts due to the crown, by the 32 Hen. VIII., c. 39, s. 75.

Estates tail are subject to the bankrupt laws, and to forfeiture for high treason by the 26 Hen. VIII., c. 13. By attainder for high treason, the estate of the tenant-in-tail, of his issue, and of all such of his collateral heirs as would have been entitled to take under the estate tail, are forfeited, but not the estates in remainder or the reversion.

The 26 Hen. VIII. extends only to cases of high treason, and therefore as to felonies the statute *De Donis* is still in force, and the forfeiture by attainder for felony extends only to the life interest of the tenant-in-tail. (Co. Litt., 392 b.)

TENANTS or TENANCY IN COMMON. [Common, Tenancy in.]

TENDER. A tender is the offer to perform some act. In practice it generally consists in an offer to pay money on behalf of a party indebted, or who has done some injury, to the creditor, or to the party injured.

A tender to the amount of 40s. may be in silver; but beyond that amount it must be in gold, or in Bank of England notes payable to bearer on demand for any sum above *5l.* (3 & 4 Wm. IV. c. 6.) If a tender be made of a larger amount in silver, or in country bank-notes, and no objection be taken at the time to the silver or notes, the objection to the tender on that ground is waived, and the tender is good to the amount to which it is made. The money must be produced and shown, or the bag or other thing which contains it shown, to the party to whom it is intended to be given, unless this is dispensed with by some declaration or act of the creditor. This is insisted upon with such strictness, that even though a party tell his creditor that he is about to pay him so much, and put his hand into his pocket to produce the money, yet if the creditor leave the presence of the debtor before the money is actually produced, no tender will have been made: but if the creditor refuse to receive the money mentioned on the ground that it is insufficient in amount, the actual production of it is not necessary to constitute a valid tender. The offer must be absolute and without conditions. An offer of a larger amount with a request of change; an offer with a request of a receipt, or on condition that something shall be done on the part of the creditor, are not valid tenders; but an offer of a larger sum absolutely without a demand of change is good. A tender may be made either to the party actually entitled to receive it, or to an agent or servant authorised to receive it, or to a managing clerk; and a tender will not be invalidated even though before it is made the creditor has put the matter into the hands of his attorney and the managing clerk of the creditor refuses to receive it, and assigns that circumstance as his reason for doing so. If the attorney write to the debtor demanding the money, a tender afterwards made to him or to his managing clerk is good, unless at the time when it is made they disclaim authority to receive the money. A tender ought to be made on behalf of the party from whom the money is due; if the agent appointed by him to make the tender offer a larger sum than he is authorised to do, the tender will nevertheless be good for the full amount to which the tender is made.

If the defendant in an action plead a tender, he must state that he has always been ready to pay the money, and he must also pay it into court. The effect of the plea is to admit the existence of a cause of action in the plaintiff. The plea goes only in bar of damages. The plaintiff, therefore, in such case can never be nonsuited: but if issue is taken on the mere fact whether or not the tender has been made, and that fact is found for the defendant, it is a good defence to the action.

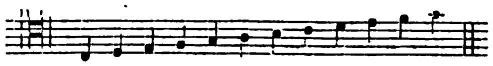
By various statutes, magistrates, officers of excise, &c., are empowered, after notice of action to be brought against them, to tender amends; and if the amount tendered is sufficient, the tender is a defence to the action.

TENEMENT, in its usual and popular acceptation, is applied only to houses and other buildings; but in its original, proper, and legal meaning it includes everything of a permanent nature that may be an object of tenure, or may be held in the legal sense, whether corporeal or incorporeal. It is sometimes applied in a more confined sense to objects of feudal tenure; in general, however, it includes not only land, but every modification of right concerning it. Thus the word "Liberum tenementum," frank-tenement, or freehold, is applicable not only to lands and other solid objects, but also to offices, rents, commons, and the like. [Estate; Tenure.] (Harg., 'Co. Litt.', 154, a. n. 7.)

TENNIS, a game in which a ball is driven to and fro by several persons striking it alternately, either with the palm of the hand, naked or covered with a thick glove, or with a small bat called a racket, held in the hand; the aim being to keep the ball in motion as long as possible without allowing it to fall to the ground. Perhaps the first historical notice of the game in England is that which Shakspere has introduced, almost in the words of Holinshed (who, however, called them Paris balls) in his 'Henry V.' (act i., sc. 2), where the Dauphin sends a present of tennis-balls in answer to Henry's demand for the sovereignty of France. Henry VII. was a tennis-player; and, as an entry in a MS. register of his expenditure in the thirteenth year of his reign mentions an item of twelve-pence for his loss at tennis and three-pence for the loss of balls, it may be inferred that the game was played abroad, as the loss of balls is not likely to have happened in a tennis-court. Be this as it may, in the 16th century tennis-courts were common in England, and the game was very popular with the nobility, which it continued to be down to the reign of Charles II., who frequently diverted himself by playing at tennis with his courtiers. A similar game was sometimes played with a hollow leather ball, inflated with air, and called a *balloon*, which was driven from one player to another by striking with the hand, or with a wooden bracer fixed upon the hand and lower arm. Further particulars respecting these and other old games played with a ball may be found in Strutt's 'Sports and Pastimes.'

TENOR, the name of the most common of adult male voices, that which is between the extremes of highest and lowest, or Contratenor [Alto] and Base. [Base-Voice.] The compass of the Tenor is from

C, the second space in the base, to G, the second line in the treble. Example, in the tenor clef:—



Hence it will be seen that the tenor and treble are reciprocally at the distance of an octave; consequently, what is calculated for the one voice, as relates to compass, will, at a distance of eight notes, invariably suit the other.

The word is derived from *Teneo, to hold;* for in ancient part-compositions, the plain-song, or air, if it may be so denominated, was given to, or *held* by, the Tenor. [Clef.]

Tenor-Clef is the C, or mean clef, placed on the fourth line for the use of the tenor-voice, as in the above example.

It is also occasionally used for the violoncello: and the part of the tenor trombone is written in this clef.

Tenor is also the English name for a larger instrument of the violin kind. See Viola.

TENSION (Mechanics), the name given to the force by which a bar or string is pulled, when forming part of any system in equilibrium or in motion. Thus, when a weight is supported by a string, the tension of the string is the weight which is suspended to it. Every point of the string may be considered as a point of application of two equal and opposite forces, downwards and upwards, each equal to the weight applied.

TENSION, ELECTRICAL. [Vapour.]

TENT, MILITARY, is a temporary dwelling-place made of canvas, which is supported by one pole, or more, and distended by means of cords, which are made fast to pickets driven into the ground: tents are set up when an army is encamped in the field either for actual service or for the purpose of performing military exercises.

The tents of the private soldiers, whether infantry or cavalry, are of a conical form with circular bases, the supporting pole or *standard* of each being planted vertically in the ground, in the centre: the standard is 10 feet 3 inches long, and the whole diameter of the tent, between two opposite pickets, is 17 feet 3 inches; but from the lower extremity of the cone, at about 2 feet from the ground, the canvas hangs down vertically and forms a cylindrical *wall*, therefore the diameter of the tent within the canvas is 13 feet 3 inches. Fifteen infantry, or twelve cavalry soldiers occupy such a tent. The round tent of an officer is 12 feet 6 inches in diameter within the walls. The marquees of officers, as well as the hospital and laboratory tents, are of oblong forms on the plan; and, in these, the canvas is supported by two standards, which are connected together at their tops by what is called a *ridge pole* 6 or 7 feet long. The length of an officer's marquee is 19 feet, and the breadth 13 feet, both dimensions being taken within the walls: tents of the two other kinds are still larger.

For the rules of modern castrametation, or the dispositions of tents in an encampment, see Encampment.

TENTHS are the tenth part of the yearly value of all ecclesiastical livings. They were formerly claimed by the pope; and his claim was sanctioned, in this country, by an ordinance in the 20th year of Edward I., when a valuation of all livings was made, in order that the pope might know the amount of his revenue from this source. The possessions afterwards acquired by the church were not liable to the payment of tenths to the pope, as all livings continued to be charged according to that valuation. (Coke, 2 'Inst.', 627.) When the authority of the pope was extinguished at the Reformation, Henry VIII. transferred the revenue arising from tenths to the crown, and had a new valuation of all the livings, so as to obtain the tenth of their true yearly value at that time. (36 Hen. VIII. c. 3, s. 9–11.) By royal grants under 1 Eliz. c. 19, s. 2, the Archbishop of Canterbury and the Bishop of London were exempted from tenths, and were also authorised to receive the tenths of several benefices as a compensation for certain estates which were alienated from their sees. By the 6 Anne, c. 24, all benefices were discharged from the payment of tenths which, at that time, were under the annual value of 50*l.*, except those of which the tenths had previously been granted by the crown to other parties. There are also some other special exemptions. Queen Anne gave up the revenue arising from tenths, as well as from first-fruits, which had been enjoyed by her predecessors since the Reformation, and by act 2 & 3 of her reign, c. 11, assigned it to the augmentation of poor livings; for which purpose she erected a corporation by letters patent in 1704 to administer the funds, called the Governors of Queen Anne's Bounty. This act declared that episcopal sees and livings not exempted should continue to pay in such rates and proportions only as heretofore, or according to the valuation of Henry VIII., commonly known as the "King's Books." Tenths under the act 1 Vict. c. 20, are collected by the treasurer of the Governors of Queen Anne's Bounty. Payment is enforced by Exchequer process, when not duly made, and the treasurer is required to give notice of arrears within one month after the proper time of payment. In case of a living being vacated, the Exchequer is empowered by act 26 Hen. VIII., c. 3, s. 16, to recover arrears of tenths, not only from the executors and administrators, but also from the successor of the last incumbent. [Benefice; First-Fruits.]

TENURE. The general nature of tenure and its origin and history in England are explained in the article Feudal Law.

All land was and is held of the crown either mediately or immediately, the tenure being either free or base; Frank-tenement or freeholding, and Villeinage. The act 12 Car. II. c. 24 abolished military tenures, which were one kind of free services, and changed them into the other species of free services, namely free and common socage; socage tenure being thus established for all lands held by a free tenure, which comprehended all lands held of the king or others, and all tenures except tenures in frankalmoigne, copyhold, and the honorary services of grand-serjeanty.

Tenure is still therefore a fundamental principle of the law relating to land in England; for the owner of land in fee simple, which is the largest estate that a man can have in land, is not absolute owner: he owes services in respect of his fee (or fief), and the seignory of the lord always subsists. This seignory is now of less value than it was, but still it subsists. The nature of the old feud was this: the tenant had the use of the land, but the ownership remained in the lord; and this is still the case. The owner of a fee has in fact a more profitable estate than he once had; but he still owes services, fealty at least, and the ownership of the land is really in the lord and ultimately in the crown. For all practical purposes the owner's power of enjoyment is as complete as if his land were allodial; but the circumstance of its not being allodial has several important practical consequences.

No land in England can be without an owner. If the last owner of the fee has died without heirs, and without disposing of his fee by will, the lord takes the land by virtue of his seignory. If land is aliened to a person who has a capacity to acquire but not to hold land in England, the crown takes the land; this happens in the case of lands being sold to an alien. If a man commits treason, his freehold lands are liable to be forfeited to the crown, and his copyhold estates to the lord of the manor. And if a man commits a felony, his freehold and copyhold lands are also subject to certain forfeitures, these forfeitures being all consequences of tenure.

Church lands are held by tenure though no temporal services are due. This is the tenure in frankalmoigne, which is now exactly what it was before the 12th of Charles II. was passed. Church lands, however, owe spiritual services, and the lord of whom they are held must be considered the owner; but the beneficial ownership can never revert to the lord, for all spiritual persons are of the nature of corporations, and when a parson dies, the corporation sole (as he is termed by an odd contradiction in terms) is not extinct, and it is the duty and right of some definite person to name a successor. When then the parson dies, the freehold may be considered to be in abeyance till the appointment of his successor, one of the few instances in the English law in which it is said that a freehold estate can be in abeyance.

No seignory can now be created except by the crown; for it was enacted by the statute Quia Emptores (18 Edw. I. c. 1), that all feoffments of land in fee simple should be so made that the feoffee held of the chief, that is, the immediate lord of the aliening tenant, by the same services by which the tenant held. But tenure of an imperfect kind may be created. Thus wherever a particular estate is created, it is held of the reversioner by an imperfect tenure: as in the common case of landlord and tenant. If no rent or other services are reserved from the tenant of the particular estate for life or years, the tenure is by fealty only, and he may be required to take the oath of fealty. But the right of the reversioner to whom services are due is solely incident to the reversion, and is created at the same time with it. The perfect tenure originated in the pure feudal system, in which the seignory of the lord was the legal ownership of the land, and the tenant owed his services for the enjoyment of it. The only perfect tenure now existing is Socage tenure, the services of which are certain, and consist, besides fealty, of some certain annual rent. And if the services due in respect of it are not rendered, the lord may distrain, that is, take any chattels that are on the land in respect of which the services are due. An imperfect tenure so far resembles a perfect one, that a reversioner can distrain for the services due from the tenant of the particular estate.

A right still incident to a seignory such as a subject may have is that of escheat, which happens when the tenant in fee simple dies without leaving any heir to the land, and without having incurred any forfeiture to the crown, as for treason. Forfeiture is another right incident to a seignory, and it may happen in consequence of any act by which the tenant breaks his fidelity (fealty) to his lord of whom he holds. It therefore extends to other cases than treason and felony. Copyhold; Escheat; Feudal System; Forfeiture; Manor; Rent.

TE'RAPHIM (תְּרָפִים; Sept., *εἴδωλα*). This is a word of somewhat uncertain etymology and signification. That the teraphim were of human form seems evident from 1 Sam. xix. 13. They appear to have been superstitiously, if not idolatrously, reverenced as penates, or household gods. (Gen. xxxi. 19, 34, 35; 1 Sam. xix. 13–17; 2 Kings xxiii. 24.) In some shape or other they were used as domestic oracles. (Comp. Zech. x. 2; Judg. xvii. 5; xviii. 5, 6, 14–20; Hos. iii. 4.) This is confirmed by 1 Sam. xv. 23, where teraphim are mentioned in connection with the arts of divination.

TERBIUM, (Tr) a peculiar metal discovered by Mosander in the state of oxide in gadolinite, orthite, &c., associated with yttria, and with oxide of erbium, another new metal.

The oxide of terbium has not yet been reduced to the state of metal; it is distinguished from that of erbium in not becoming of a dark orange-yellow colour when heated in the air. The oxide of terbium is insoluble in water and in the caustic alkalies; it is soluble even after heating to redness in a boiling solution of carbonate of soda, but after a few days it separates from solution in the state of a double salt; the carbonate of terbium is soluble in solution of carbonate of ammonia, and after saturation forms with it in a few hours a double salt, which separates in such quantity that very little of the oxide remains in solution; the salts of this oxide are colourless and have a sweetish taste. The sulphate is more soluble in cold water than in hot; the nitrate yields by evaporation a crystalline mass which deliquesces in a moist atmosphere.

The oxide of terbium has hitherto been obtained in small quantity only, and its properties are but little known.

TEREBENE. [TURPENTINE.]

TEREBENTHIN. [TURPENTINE.]

TEREBENZIC. [TURPENTINE.]

TEREBIC ACID. [TURPENTINE.]

TEREBILIN. [TURPENTINE.]

TERECHRYSIC ACID. [TURPENTINE.]

TERENTIAN METRES. Few subjects connected with Latin literature have been treated with less success than the principles and laws which govern the metres of Latin comedy. The majority of readers seem to look upon the writings of Plautus and Terence as mere humble prose arbitrarily distributed so as to present to the eye the appearance of verse without its realities. For them it would be better if the whole were printed consecutively, and such an arrangement would in fact be supported by not a few of the existing manuscripts. On the other hand, there have been writers who have laboured to remove the difficulties that obscure the subject, among whom none before Bentley and Hermann appear to have had any success. Since their time, Bothe, Ritschl, and Fleckeisen have done good service, although the first and second of these recent critics have too frequently been rash in their innovations. Even the writer of the Life of Terence, in the 'Biographie Universelle' (published in 1826), gave the following extraordinary criticism upon the metres of Terence:—"The sole rule which he observes with tolerable regularity is to end each verse with an iamb; and even this limitation he often disregards, as, for instance, in the terminations *hic consiste; si vis, nunc jam; audio violenter; huc adducam; hanc renturam*, &c. With regard to the other feet, he freely substitutes for the iamb or spondee, a trochee, anapest, dactyl, double pyrrhic, or four short syllables, and a cretic or short between two longs," &c. This writer thus started with the false impression that all the verses of Terence are reduced by critics to the single metre, called trimeter iambic; whereas in fact all who have dealt with the subject, except himself, are aware that the poet has at least three forms of verse which end trochaically; and his second exception is disposed of by the more correct orthography *nunciam*. In England, again, so late as the year 1837, we had a scheme of the Terentian meters, which for the commonest of those metres, the trimeter-iambic, gave us the following scale:—

⏑ –	⏑ –	⏑ –	⏑ –	⏑ –	⏑ –
– –	– –	– –	– –	– –	– –
– ⏑ ⏑	– ⏑ ⏑	– ⏑ ⏑	– ⏑ ⏑	– ⏑ ⏑	
⏑ ⏑ ⏑	⏑ ⏑ ⏑	⏑ ⏑ ⏑	⏑ ⏑ ⏑	⏑ ⏑ ⏑	
⏑ ⏑ –	⏑ ⏑ –	⏑ ⏑ –	⏑ ⏑ –	⏑ ⏑ –	
	⏑ ⏑ ⏑ ⏑		⏑ ⏑ ⏑ ⏑		

with the additional remarks that *quo quid hunc* may be a dactyl, that *hic quidem est, studet par*, and the three first syllables of *voluptati*, may pass for anapests, &c., &c. All this is exceedingly unsatisfactory, and it would be better to abandon the problem as insoluble, than to give currency to extravagancies which would enable us to find in any given chapter of Cæsar a series of trimeter-iambics.

It must be admitted that the metres of the Greek dramatists, and more particularly of the tragedians, gratify the ear with rhythms which, comparatively speaking, are smooth and appreciable. But it should be recollected, in the first place, that the Greek language is distinguished from among other languages by its abundance of words which end in a short syllable, and the advantage to the poet is increased by the large number of instances where these short final syllables have a vowel ending. Compare, for instance, the accusatives singular *μουσαν, δουλον, πολιν, δαιμονα*, with the Latin *musam, servom, navim, leonem*; the nominative and accusative plural *δαιμονες, δαιμονας*, with the Latin *leonēs*; the numerals *ἑπτα, δεκα*, with the Latin *septem, decem*; the verbs *τυπτετε, τυπτουσι*, with the Latin *scribitis, scribunt*; the pronouns *με, σε, ἑ*, with *mē, tē, sē*. In fact the Latin language exceeds the Greek in the number of long syllables, as much as the English and German languages exceed the Latin.

A still more important matter is the question whether, and how far, the written language of the Romans is an exact representative of the spoken language. It seems to be a condition of language in general that its pronunciation should always be passing through a series of changes, and that those changes should consist for the most part in the gradual omission of letters and even syllables. Thus the Roman phrase *mea domina* is in Italian *madonna*; in French, *madame*; in English, *madam, ma'am*, and even *mum* and *mim*. Meanwhile, for the most part, the changes in orthography are slow, and consequently nearly always in arrear of the orthoepy. Thus it will be found that the sounds of English and German words which appear to the eye so weighed down with consonants, are in the mouth of a native tolerably harmonious. Was such the case with the Roman also? We answer with little hesitation in the affirmative, partly because the laws which now govern language can scarcely have been wanting in ancient Italy, and partly because we find the point established by several incidental remarks in Latin writers. Thus Suetonius says, in his 'Life of Augustus (c. 88), "Orthography—that is, the laws and principles of writing laid down by grammarians—he was not very observant of, but seems rather to follow the opinion of those who hold that we should write as we speak. For as to his hâbit of changing or omitting not merely single letters, but even whole syllables, that is a common error." It should be observed, too, that Suetonius had himself seen the handwriting of the emperor. (Ibid, c. 87.) Again, Quintilian ('Inst.,' xi. 3, 33) says, "As, on the one hand, it is essential that every word should be clearly articulated, so, on the other hand, to reckon up, if we may so speak, every separate letter, is painful and wearisome." In the same chapter he further observes, "Not only is a coalition of vowels very common, but *some* too of the consonants are disguised (*dissimulantur*), when a vowel follows;" where he must refer to some other letter than *m*, probably the final *s* generally and the final *d* of neuter pronouns. Moreover, Priscian, who by the way appears to have written when the Latin language had ceased to be spoken as a living tongue, at times throws out such conjectures as the following:—"I think that *vigil, vigilis*, should rather be pronounced *per syncopam*." We might appeal to Cicero's authority for the fact that a final *s* was frequently omitted in pronunciation. But there are still other arguments in support of the principle for which we are contending. Within the limits of the Latin language itself we find such changes actually in progess—as, *magis, nisi, ipsus, neque, atque, sive, neve, videris, viderunt, providens, mihi, nihil, quibus, populus, tegumen, opera, potesse, mavolo, noverit, novisti, coventio*, becoming severally *mage, ni, ipse, nec, ac, seu, neu, vĭdēre, vīdēre, prudens, mi, nil, quis, poplus* (compare also *poplicus*), *tegmen, opra, posse, malo, norit, nosti, contio*. Principles of etymology would enable us to carry the list out to a vast extent, and this still more, if we employed the analogies of the Greek tongue.

Again, the languages which are acknowledged to be derived from the Latin, such as that of the Troubadours, the Italian, French, Spanish, Portuguese, and one portion of the English, by their shortened forms, confirm our views. And this will be found to be specially the case with the French. To those who may express their surprise that the French should thus take precedence in our argument of the Italian, the answer is, that the French is probably derived from the Latin more completely than even the Italian; for the Celtic, Teutonic, and Iberic languages spoken in France before the Roman conquest of that country were of too foreign a character to mix with the language of conquerors or to supply the place of it in the intercourse of the provincials with their masters; whereas in Italy there already existed dialects which were intelligible to those who came from Rome, and for that very reason were not supplanted by that particular form of the Italian language which happened to prevail in the metropolitan city. In the same way the authorised dialect of our own tongue is more likely to become the current language of Calcutta than of Yorkshire. Add to this that the language now called Italian belongs to Tuscany, not to Rome.

Lastly, we find much to strengthen our present argument in the abbreviated forms of writing which were in use among the Romans, and are still found in manuscripts. Thus the word *consul* is written *cos*, because the *n* was not pronounced before *s*, as Diomedes expressly tells us. (Putsch.,'428.) Again, the word *modo* not unfrequently occupies such a position in the verses of Terence as to seem to require a monosyllabic pronunciation, such indeed as seems also more consistent with its enclitic character. This very word enters into the composition of the Latin *quomodo*, which again in the languages derived from Latin assumes various forms: in the Romance, *com*; in Spanish, *como*; in Italian, *come*; and in French, *comme*. To this we now add the fact that the Romans themselves represented the simple word by the abbreviation *mō*. Again, ·*n*· is the manuscript mode of denoting the conjunction *enim*, a word which must often be pronounced like *en* to fulfil the conditions of Terence's metre. We may observe of this word, as of *modo*, that an enclitic should not attract the attention of the ear. A third example shall be a third enclitic, namely, *quidem*. Bentley himself observed the trouble caused by this word in the verses of Terence ('Andr.,' i. 3, 20), and his remedy is to drop the final *m*, which however still leaves the verse encumbered with a superabundance of syllables. We contend that this also is commonly a monosyllable, and on the following grounds:—First, the metre of Terence requires it. Secondly, if *ĭtidem* has a reduced form, *item*, analogy will give us *quem* for *quidem*. Thirdly, the Romans, like the French, did not pronounce the vowel *u* after *q* (otherwise such words—*ăqua*, or *nĕque*, for instance—would have had the first syllable long), and they also disguised the final *m*, as Quintilian implies in the passage to which we have already referred. Thus we have arrived at a sound *ke*. Now the

Greek language has a word of precisely the same power and character, *γε*, which we strongly suspect to be the very same word; so that, if our suspicions be right, *equidem* and *εγωγε* are of one origin, as well as of one meaning. Lastly, there are reasons still remaining which demand a monosyllabic pronunciation for *quidem*. We have already called it an enclitic, and it appears beyond dispute in that character in the words *equidem, siquidem, quandoquidem.* Now an enclitic should in its nature sacrifice itself to give tone to the word which precedes it. Yet if we believe the ordinary teachers of Latin prosody, *equidem*, though a corruption from *egoquidem*, or *egquidem*, has the first syllable short. Again, *quando* by itself has the final *o* common, to take the most unfavourable view; for in the poets of the Augustan age it would be difficult to find a single example where *o* is short; and in *quandoque, quandocunque,* the vowel is always long. But add *quidem*, and they say *quandoquidem* has the same vowel always short. So also *si* in *siquidem*, according to their views, loses its length the moment the enclitic attaches itself to it. If our views be right, the true pronunciation of these three words may be represented by something like *ēke, quandōke, sīke;* the last corresponding to the Greek *ειγε*. We will here observe, in passing, that our pronunciation of *quidem* suggests a correction of a corrupt passage in Persius, Sat. i. 10:—

"Littera. Per me quidem sint omnia protinus alba."

The current reading is *equidem;* and, relying upon one error, the editors have allowed the same *equidem* to stand with *dubites* in Sat. v. 45, when the context, as well as grammar, requires *dubitem*. It may also be noticed that Ritschl, in his 'Parergon,' says that the employment of *quidem* as a monosyllable is a very ordinary occurrence.

But to return to the subject before us. It is not uncommon with critics to imagine to themselves that the laws of Greek and Latin verse are based upon principles essentially different from those of modern languages; the former depending, they say, upon the length of syllables, the latter upon accent. This distinction we believe to be wholly without foundation. We rely little upon the fact that Priscian's treatise headed 'De Accentibus' is only a schoolboy-like scanning of the first lines in the 'Æneid,' because, as has been already said, that writer's authority is not of great weight in what concerns the spoken tongue; and in fact, for the same reason, there is little dependence to be placed upon the dogmas of the other so-called grammarians, such as Diomedes. Our views upon this subject are rather derived from the perusal of Terence and Plautus themselves, and are confirmed to a considerable extent by the hexameters of Virgil and the lyrics of Horace. They also seem to be supported by the general principles of language. We will endeavour briefly to state the results at which we think we have fairly arrived.

I. In words of more than two syllables, if, according to the received prosodies, two or more short syllables, exclusive of the final syllable, occur together, the second of those short syllables, counting from the beginning of the word, was slurred over. For instance, in some cases the changing a vowel *i* or *e* into the sound of a *y*, or of a vowel *a, o*, or *u* into the sound of a *w*, would be the simplest mode of effecting such a result. Thus, *adtrĭbŭĕre, pĕrĭmus, consĭlium,* would, upon our theory, be pronounced *adtribwere, peryimus, consilyum,* the last of which is confirmed by Horace's use of the same word in his odes, and the Italian *consiglio*, Fr. *conseil*, Sp. *consejo;* and at any rate our pronunciation of the two former is more consistent with the quantity of the vowels than the mode usually adopted, namely, *per-ĭ-imus, adtribŭere.* Bentley has himself observed ('Eun.,' ii. 2, 36) that the words *mulier, mulieris*, &c., are always so placed in Terence as to have the accent on the first syllable; which, by the way, is consistent with the Italian *moglie*, and the Spanish *muger*. We doubt, however, whether the dative and ablative plural would be found to obey the law laid down by Bentley. In those cases where the second short vowel is followed by a consonant, the abbreviation proposed becomes impracticable, if at least that consonant be really to be sounded. In such cases the right course is probably to drop the syllable altogether. Thus *miseria, familia,* and such words, Hermann ('De Re Metrica') truly says, are to be pronounced with the accent on the first syllable, and this in defiance of the law laid down by all the grammarians, that the accent cannot be carried farther from the end of a word than the antepenult. Hermann has not attempted to reconcile the two assertions, but they fall at once into agreement if we are right in dropping the second syllable, for then the first becomes virtually an antepenultimate; and we are only doing what is common in our own language, as in *évery, lóvely*. This principle, moreover, may be clearly traced in forms acknowledged to be Latin. Thus, from *populus* should be formed *populicus*, but that becomes *poplicus* or *publicus*. If *pello* has a perfect *pepuli, cado* a perfect *cecidi;* the compounds with *re* should strictly give us *repepuli, rececidi;* but we find *reppuli, reccidi*. Again, in connection with *opifex* we ought to have *opificium* and *opificina;* but these have been supplanted by *officium, officina*. So, too, the Greek *επιπεδον* becomes in Latin *oppidum*, as opposed to the *arx*, or citadel; and the adverb *επιπεδως* takes the form of *oppido*, an equivalent in meaning to *plane*.

II. The accent of a Latin dissyllable or polysyllable will fall upon the penult, if long. Where that penult is long by the nature of the vowel, and at the same time the final syllable is short, the accent upon the penult is called a circumflex; in other cases an acute accent. Secondly, if the penult be short, put an acute accent upon the antepenult, always performing the previously mentioned abbreviation, if need be; the necessary effect of which is to give a long antepenult, if the penult itself be short.

III. The preceding rules dispose of every case except two classes of words, namely, dissyllables with a short penult, and monosyllables. The former are either to be pronounced as monosyllables, or else to be attached to the preceding or following word; and the double word thus formed to be accentuated as a polysyllable. When a word is attached in pronunciation to that which it precedes, it has already received in common use the name of enclitic. Hermann, who first observed that there are also words which attach themselves to those which follow, has proposed to give them the name of proclitics. The Greek article, for instance, belongs to this class, as also not unfrequently the Latin *hic, hæc*, &c. The same is true of prepositions, when really prepositions, that is, when they precede their noun; and the Latin *non* or *ne*, like the Greek *ου*, should perhaps in many cases be pronounced in immediate connection with the following verb, just as we, who are accustomed to place our *not* after a verb, write *cannot* as a single word. Many little conjunctions also may probably require such treatment, as *si, ut*, &c.; in confirmation of which it should be observed that Latin manuscripts, even of a late date, almost habitually write these little words in immediate connection with the following word. Again, the list of enclitics should be extended so as to include most of the conjunctions which require to be placed second in a sentence, and even conjunctions in general, together with the relative itself when they are forced, if the word may be used, into a second place, as, for instance, in the first line of the 'Æneid,' which acquires additional power by the pronunciation *Troiaé-qui*. In the same way a postponed preposition becomes an enclitic, as in the phrase *altís-de montibus*. In this way many dissyllables and monosyllables will coalesce into polysyllables, and be accentuated accordingly. We even entertain a strong suspicion that a verb in the middle of a sentence must often be treated as an enclitic, to give tone to some important word before it. Such a pronunciation was indeed demanded by Carey, in his 'Prosody,' for the Virgilian *levís-volat*. The verb *est*, again, is known to have been very generally an enclitic; and the best Sanskritists have held that the verb must very frequently in verse be so attached to the word which precedes it. We trace the same law in a fact which governs the order of words in the Latin and Hungarian, and probably many other languages, namely, that when a verb occupies a place in the middle of its clause, it is safe to infer a strong emphasis for the word which precedes it.

IV. The principle of elision will often modify the accent of a word. Thus, *cumprímum, scribéndum, arguménto,* would in ordinary circumstances have the accent as marked. But if elision take place, they sometimes have the accent displaced. In this way the first and eleventh lines of the Prologue to the 'Andria' should be read: "Poéta cúm-prim, âm' adscríbend' ádpulit;" and "Non it' dissím'li sunt argúment' ét-tamen." It should also be observed that elision often destroys the initial vowel of the second word, instead of the final syllable of the preceding word, as *nunc tuúmst offícium*, rather than *nunc tu' ést offícium*.

V. The pronunciation of Latin words in the days of Plautus and Terence differed in several respects from that which holds good for the later poets, and this for the most part in one direction—syllables being long in the old Latin drama, which afterwards became short. Thus, *lārŭă* and *milŭŭs, gratĭīs* and *nunciam*, were always trisyllabic. The first syllable of *Acheruns* was already in a state of transition, generally long, yet at times short; *cacula* is another word of varying quantity in the same syllable. Then, again, nominatives in *or*, as *uxōr* (Plaut., 'Stic.,' v. 140), *stultiōr* (Ibid., 'Bacc.,' v. 123), may have the last syllable long, and this with the more reason as they really stand for *uxors, stultiors*. In the same way, *pater*, like the Greek *πατηρ*, has a long final syllable in the 'Trin.,' v. 645, if we follow the Ambrosian palimpsest. Then, again, in verbs we have a long final in the first person of the reflective, as *perpetiōr* ('Most.,' v. 621), and in the third person singular of the active, provided the other parts of the tense in question prove the vowel to be in itself long, as *sīt* ('Mil.,' v. 242), *adflictāt* ('Merc.,' v. 648), *habēt*, not *aut habet* ('Trin.,' v. 206), *desiderēt, expectet,* for so the MSS. ('Mil.,' 244), and, above all, in perfect tenses, as *optigit* ('Stic.,' v. 384), *astitīt* ('Mil.,' v. 213), *repperīt* ('Stic.,' v. 462), *vendidīt* (Capt. Prol. 9). Indeed, Virgil and the later poets furnish not a few examples where such syllables retained their original length, as, *patēr, amōr*, in Virg., *perrupīt, subiīt*, Hor., *rediīt, præteriīt*, Ov. On the other hand, a short vowel in what is called doubtful position, remained invariably short in Plautus and Terence, although the later poets took the liberty of treating such a syllable as long. Thus, *lacruma, sacrum, lucrum, patrem*, have always a short first syllable in Latin comedy; and if *mediocris* has a long *ō*, it is because the *o* vowel of this word is in itself long.

If now the principles we have assumed on the grounds above mentioned be applied to the plays of Terence, we arrive at the result, that the verses, with very few exceptions, acquire the desired rhythm; and that there should be exceptions must be expected where the text of an author is not yet established upon a careful comparison of manuscripts, and where even the transposition of two words will often alter the accent. Moreover, it should always be recollected that in the comic drama it may be even desirable to avoid the purer rhythm of verse, and approach somewhat to the prose of natural conversation, as Cicero has himself remarked (' Orator.,' 55). That what we now say may be put to the test, we will give a list of those words requiring abbreviation which most commonly occur, observing at the same time that a word at the end of an iambic trimeter, or after a monosyllable, is often to be pronounced with all its syllables, though elsewhere liable to contraction. Of this an example may be seen in the tenth line of the prologue already referred to, which contains both *noverit* and *norit*:—

senex = *sen.* Compare the genitive.
pater = *père.* Compare *parricida.*
soror = *sœur*, as in French.
voluntas = *vountas.* Compare *vīs* = *vŏlis* and *invitus* = *involitus.*
lacruma = *larma.* Compare the French *larme* and *serment*, from *sacramentum.*
hodie = *oggi*, as in Italian.
dies = *jes.* Compare *jour*, *journée.*
ego = *yo.* Compare Italian *io.*
cave = *cau.* Compare Cicero's story about the word *cauneas.*
tace = *tai*, as in French, *tais.*
quibus = *quis.* Compare the loss of *b* in the dat. pl. of the first and second declensions.
tibi = *ti.*
sibi = *si.*
ibi = *i* or *y.*
ubi = *ou.*
} Compare the Romance, Italian, Fr., Sp., and *mihi* = *mi.*
abi = *ai.*
jube = *ju.* Compare the perfect *jussi.*
inde = *in.* Compare the French *en*, and Latin *dein*, *exin*, for *deinde*, *exinde*, &c.
redi = *rei.*
magis = *mais.* Compare *mai* It., *mais* Fr., *mas* Sp,
minus = *mins.*
alius = *alyus.* Compare Greek *αλλος*, and Sanskrit *anya.*
facere = *fare.* Compare Fr., It., Sp.
vigilare = *vigliare.* Compare Fr., It.
vide = *vi.* Compare Fr. *voi-ci*, *voi-la.*
novos = *nous.* Compare Greek *νεος*, English *new.*
sine = *sin.* Compare Fr., It., Sp.
duo = *do.* Compare Greek *δω-δεκα*, Fr., Eng.
ille, &c. = *il* or *le*, &c. Compare It., Fr., Sp.
bonus = *bon*,
sumus = *sommes*,
} as in French.
bene = *ben.*
male = *mal.*
homo = *homme*, as in French.
rei = *re.* Compare the forms of the fifth declension used by Cæsar, Virgil, &c.
puer = *pur* or *por.* Compare Greek *παις*, Spartan *ποιρ*, Latin *Lucipor.*
suus, &c. = *sus* or *sos.*
meus, &c. = *mus*, &c.
tuus, &c. = *tus*, &c.
} Compare It., Fr., Sp., and also the forms used by Ennius, and in Greek.
fuit = *fut.* Compare It., Fr., and Latin *fore.*
animus = *âmus.* Compare It., Fr.
asinus = *ânus.* Compare Fr.
edepol = *epol.* Compare *ecastor*, *ecere*, &c.
legere = *lere.* Compare Fr.
oculus = *œilus.* Compare Fr.
generis = *genris.* Compare Fr.
aperire = *aprire.* Compare It., Fr., Sp.
opera = *opra.* Compare the form in Ennius, and Fr., Sp.
similis = *sim'lis.* Compare Fr. *semble*, Eng. *resemble.*
tamen = *ta'n.* Compare *tametsi* for *tamenetsi*, and *tandem* for *tamendem.*
aliquis = *alquis.* Compare It. *alcuno*, Fr. *aucun*, from *aliquis-unus.*
hujus = *his.* Compare the abbreviation of *nullīus* into *nullĭus* and *nulli.*
ejus = *is.*

For a more detailed exhibition of these words, see 'Journal of Education,' vol. ii., p. 344; and on the subject of Latin prosody generally, the same work, vol. iv., p. 336.

It should be added, that of modern editors, Hermann, Bothe, Lindemann, Ritschl, and Fleckeisen, alone seem to have a distinct idea of the nature of the metres of Terence and Plautus; for all that has been said applies to Plautus as well as Terence. The author of the 'Varronianus' borrowed his article on the subject, and that without acknowledgment, from the 'Penny Cyclopædia' and the paper in the 'Journal of Education;' all, at least, except the paragraph about *puella*, and that, oddly enough, is the one paragraph in the said chapter which the recent editor of Terence has justly condemned. Among older writers, Bentley certainly possessed a clearer insight into the subject than some of his notes would lead one to suppose. That this is the case is proved by an anecdote in Bishop Monk's 'Life' of that scholar. The reverend doctor, dining at a friend's house in London, kept the gentlemen longer over their wine than was thought proper by the ladies in the drawing-room, and added to the scandal when his voice was heard, even above stairs, in what was supposed to be a song to the tune of 'Unfortunate Miss Bailey.' The doctor was only reading to them some specimen of Terence's Comic Septenarius, or, to use a harder phrase, the Iambic Tetrameter Catalectic.

TEREPHTHALIC ACID. [TURPENTINE.]

TERETINIC ACID. [TURPENTINE.]

TERM (Algebra). A simple term in an algebraical expression means all that involves multiplication, division, and extraction of roots without addition or subtraction. Thus in the expression

$$a^2b^3x^2-2abx^3+\sqrt{ab}\,.\,x^4,$$

the terms are $a^2b^3x^2$, $2abx^3$, and $\sqrt{ab}\,.\,x^4$. But compound quantities are also called terms when they are put in such a form that additions and subtractions are subordinate to subsequent multiplication, division, or extraction. Thus,

$$(a+b)\,x^{c+d}+\sqrt{(a^2-b^2)}\,.\,xy$$

has two terms, $(a+b)$, x^{c+d}, and $\sqrt{(a^2-b^2)}\,.\,xy$. If the form be altered into

$$ax^{c+d}+bx^{c+d}+\sqrt{(a^2-b^2)}\,.\,xy,$$

the expression then has three terms. Most frequently, however, there is one letter in powers of which the whole expression is arranged, and then all that involves any one power of this principal letter is a term. Thus $a+bx+cx+ex^2$ has three terms, namely, a, $(b+c)\,x$, and ex^2.

When one quantity is said to be expressed in terms of another, it generally means merely that the first is to be an explicit FUNCTION of the second. Thus, in $x+y=a$, we have expressed $x+y$ in terms of a: deduce $y=a-x$, and we have y expressed in terms of a and x. This is the distinction between y being expressed in terms of x, and y being a function of x: if, for instance, $y=a-z$, $z=x^2+x$, y is a function of x, but it is not expressed in terms of x, but of z; substitute for z its value, and y is then expressed in terms of x. It is to be remembered that by saying that a quantity is expressed in terms of x, it is not meant that x is the only letter which enters, but that no other letter if there be any, is a function of x. Thus, in the preceding, where we obtain $y=a-x-x^2$, y is expressed in terms of x if a be no function of x. But if a be a function of x, say x^3+x, then y is not expressed in terms of x, until the value of a has been substituted, giving $y=x^3-x^2$.

TERM. The law Terms are those portions of the year during which the courts of common law sit for the dispatch of business. They are four in number, and are called Hilary Term, Easter Term, Trinity Term, and Michaelmas Term: they take their names from those festivals of the Church which immediately precede the commencement of each. Various acts of parliament have been passed relative to the regulation of the Terms. The statute which now determines them is the 11 Geo. IV. & 1 Wm. IV. c. 70, amended by 1 Wm. IV. c. 3, which enacts that Hilary Term shall begin on the 11th and end on the 31st of January; Easter begin on the 15th of April and end on the 8th of May; Trinity begin on the 22nd of May and end on the 12th of June; Michaelmas begin on the 2nd and end on the 25th of November. Monday is in all cases substituted for Sunday when the first day of Term falls on Sunday. During Term four judges sit in each court, and are occupied in deciding pure matters of law only, without the intervention of a jury. The courts are empowered however to hold sittings out of Term for the purpose of disposing of the business then pending and undecided before them.

TERM OF YEARS signifies the estate and interest which pass to the person to whom an estate for years is granted by the owner of the fee. [ESTATE.]

TERMINAL. We cannot say that this term *is* used in mathematics to the extent to which we shall carry it; but the very great convenience which would arise from an extension of its use is sufficient justification for coining a few new meanings. Term is a word of geometry very little used, and signifying boundary or extremity; the words terminal value and terminal form are sometimes used to signify the last and most complete value or form. When a finite expression, added to a certain number of terms of a series, makes up the equivalent of the expression from which the series is deduced, or stands for all the subsequent terms of the series, this finite expression might be called the terminal expression. Thus in Taylor's Theorem we have one terminal expression in D'Alembert's form, another in that of Lagrange.

There is also another use of the word, which would convey a distinction much wanting words to express it: we allude to what might be called *terminal language.* All the use of the words infinitely small and infinitely great [INFINITE; LIMIT] is entitled to this name; as follows:—When we say, for example, that a circle *is* a regular polygon with an infinitely great number of infinitely small sides, the language used is that of an end arrived at, a transformation actually made; the circle is described as actually consisting of straight lines; and the language is *terminal* (expressive of a boundary actually attained). But the meaning of this language is, or is generally held to be, false: no polygon is a circle, how great soever the number, or how small soever the magnitude, of the sides. The proposition which is really true, that is, over which all shake hands, whatever their notion of infinity may be, is that the terminal proposition, true or false, is one to which an interminable and unlimited degree of approximation may be made. An inscribed regular polygon may, with sides enough, be made to coincide with the circle within any degree of nearness we please to assign: or the following proposition—"the area of the inscribed polygon may be made to differ from that of the circle by less than the *n*th part of the latter"—may be made true for every value of *n* that can be named, however great. Terminal language, properly employed, may be made the means of abbreviation of all those truths whose announcement contains interminable approximation: the development of this sentence is the object of the article INFINITE.

TERMINALIA, the festival of Terminus [TERMINUS], celebrated at Rome annually on the 23rd of February, the last day of the old Roman year. The festival was either public or private, according as it was held at the boundaries between the fields of private persons, or at the boundary of the Ager Romanus. In the former case persons possessing adjoining lands met with their families and servants at the stone which divided the properties, adorned it with garlands and offered sacrifices, and a feast in which the neighbours partook was intended to renew the friendly relations existing between them. (Ovid., 'Fast.' ii., 643, &c.) Dionysius states that down to his time the Romans did not offer any bloody sacrifices on this occasion, but only cakes and fruit. But we have authentic statements which show that the assertion of Dionysius can only apply to the early period of the republic, and that subsequently a lamb or a sucking pig was sacrificed. (Dionysius ii., 74; Plutarch, 'Numa' 16; 'Quaest. Rom.' 15; Horatius, 'Epod.' ii. 59.) The public Terminalia were solemnised in a similar manner by the whole people on the boundary of the Ager Romanus. (Ovid., 'Fast.' ii. 679, &c.)

TERMINUS, a Roman deity whose worship was said to have been introduced by Numa Pompilius, when he ordered the fields of the citizens to be separated from one another, and the boundaries to be marked by stones which were to be considered as sacred to Terminus, or as Dionysius calls him Ζεὺς ὅριος. (Festus, s. v. 'Terminus,' Dionysius, ii. 74). A careful examination of the worship of this god shows that Terminus was only a surname of Jupiter, who was worshipped under this name as the guardian of boundaries. The stone pillars were regarded as symbolical representations of the god himself, and hence perhaps the severe law mentioned by Festus, that whoever displaced such a pillar should, together with his oxen, be devoted to the god. In the same manner in which the boundaries between the lands of private individuals were marked, the original territory of Rome (Ager Romanus) was separated by pillars from the territory of neighbouring tribes. In the direction of Laurentum there was such a pillar (terminus) between the fifth and sixth milestones from Rome on the Laurentine road. This was the public Terminus. The god had a temple on the Capitol, and the part of the roof just above the symbolical pillar was left open. (Festus; Servius, 'Ad Aen.' ix. 448.)

TERMINUS, or TERM, signifies, in sculpture and architecture, a pillar statue, that is, either a half statue or bust, not placed upon, but incorporated with, and as it were immediately springing out of the square pillar which serves as its pedestal. If they be mere busts, figures of this kind are usually distinguished by the name of HERMÆ (Ἑρμαῖ); and busts which, instead of having a circular moulded base, resemble the upper part of a terminus, are called terminal busts. There are many such busts and also some termini in the Græco-Roman Saloons of the British Museum; among others a terminal bust of Dionysus, and a double terminal bust of Bacchus and Libera, both of which are engraved under DIONYSUS; also a terminal statue of PAN. The terminus, or pillar part, is frequently made to taper *downwards*, or made narrower at its base than above, which mode of diminution, the reverse of that employed for columns, was no doubt intended by way of similarity to the general outline of the human figure, whose greatest breadth is at the shoulders. By modern artists the pedestal part is usually made tapering downwards or narrowest just above its base; when it is called the *gaine*, from its resemblance to the scabbard of a sword.

In architectural design *Terms* are employed in lieu of Caryatides, not however as insulated pillars, but as pilasters forming a small order or attic, or a decoration to gateways, doors, &c. They frequently occur in the Renaissance and our own Elizabethan style.

TERMS, ATTENDANT AND SATISFIED. The assignment of satisfied terms on the purchase of property being frequently accompanied by great difficulty and expense, the Act 8 & 9 Vict. was passed to render the assignment of Satisfied Terms unnecessary.

TEROPIAMMON. [OPIUM, ALKALOIDS OF.]

TERPIN. [TURPENTINE.]

TERPINOL. [TURPENTINE.]

TERPSICHORE. [MUSES.]

TERRA SIENNA. [COLOURING MATTERS.]

TERRESTRIAL LIGHT. Aurora borealis, or northern lights, as they have hitherto been called, is now generally admitted to be a magnetic phenomenon. [TERRESTRIAL MAGNETISM.] As lightning shows a restoration to equilibrium from a disturbance in the electrical condition of the atmosphere, so these northern and southern lights denote the conclusion of a magnetic storm which has foretold its approach by its universal influence on a freely-suspended magnet, even at places far distant from the place where the phenomenon itself is visible.

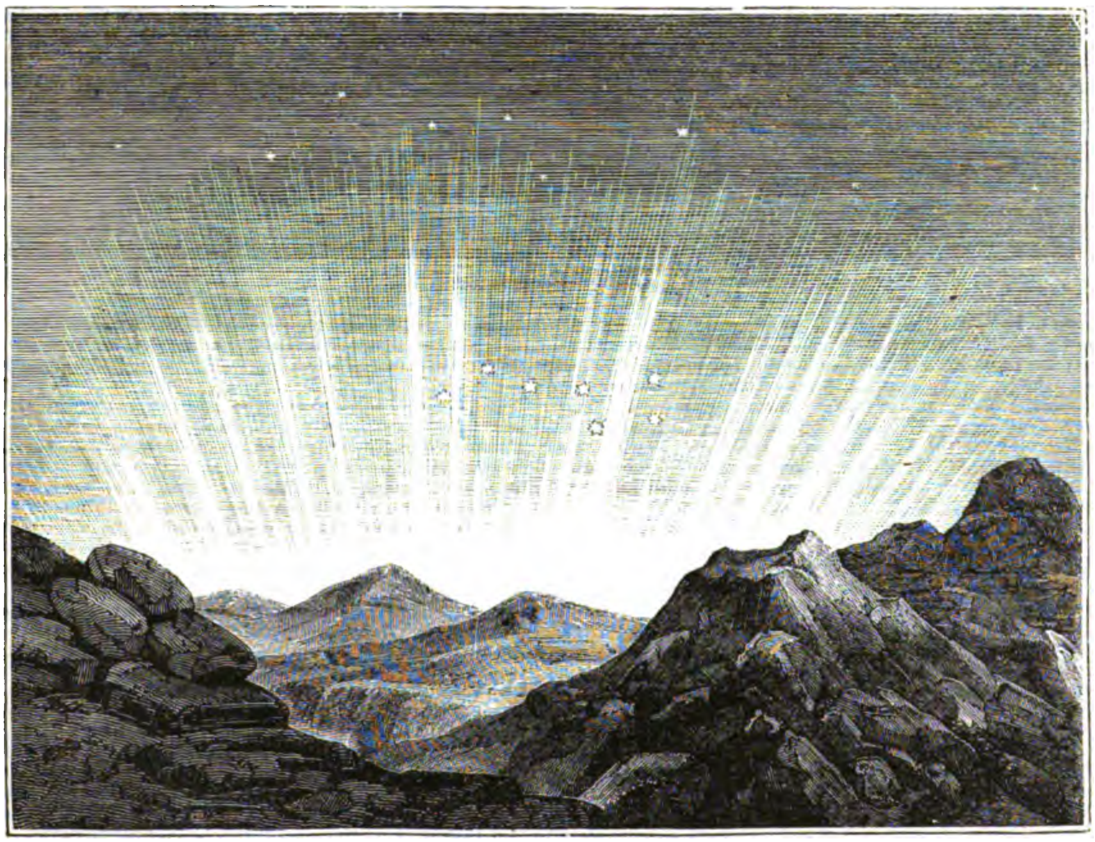


Fig. 1.—Aurora Borealis.

The appearances which ordinarily present themselves during a display of terrestrial light are thus graphically described by Humboldt with his accustomed accuracy:—"Deep in the horizon, nearly in the situation where it is intersected by the magnetic meridian, the heaven, up to this moment clear, grows black. There is a kind of hazy bank or screen produced, which rises gradually and attains an altitude of from 8° to 10°. The colour of the dusky segment passes over into brown or violet. Stars are visible in it, but they are seen as in a portion of the sky obscured with dense smoke; a broad bright luminous arc or seam, first white, then yellow, bounds the dusky segment. The highest point of the luminous arc, when it has been carefully measured, has been found to be not exactly in the magnetic meridian, but to vary between 5 and 18 degrees from it, towards the side on which the magnetic declination of the place of observation lies. The luminous bow, in constant motion, flickering and changing its form incessantly, sometimes remains visible for hours before anything like rays and pencils of rays shoot from it and rise to the zenith. The more intense the discharges of the northern lights, the more vividly do the colours play from violet and bluish-white, through every shade and gradation, to green and purplish-red. The magnetic fiery columns shoot up, at one time singly from the luminous arch, even mingled with the rays like thick smoke; at another, many columns arise simultaneously from several and opposite points of the horizon, and unite in a flickering sea of flame, to the splendour of which no description can do justice, and whose luminous waves assume another and a different shape every instant. The intensity is at times so great that Lowenörn perceived its oscillations, in bright sunshine, on the 29th of January, 1786. The motion increases the brilliancy of the phenomenon. Around the point of the vault of heaven which corresponds with the direction of the dipping-needle, the rays at length collect together, and form the corona or crown. This surrounds the summit, as it were, of a vast canopy, the dome of heaven, with the mild radiance of its streaming but not flickering rays. It is only in rare instances that the phenomenon proceeds the length of forming the corona completely. When its appearance, however, the whole is at an end. The rays now become rarer, shorter, less intensely coloured. The crown and the luminous arches break up. By-and-bye nothing but broad, motionless, and almost ashy-gray pale gleaming fleecy masses appear irregularly dispersed over the whole vault of heaven: these vanish in their turn, and before the last trace of the murky fuliginous segment, which still shows itself deeply on the horizon, has disappeared. Of the whole brilliant spectacle, nothing at length remains but a white delicate cloud, feathered at the edges, or broken up, as a cirro-cumulus, into small rounded masses or heaps, at equal distances." ('Cosmos,' v. i.)

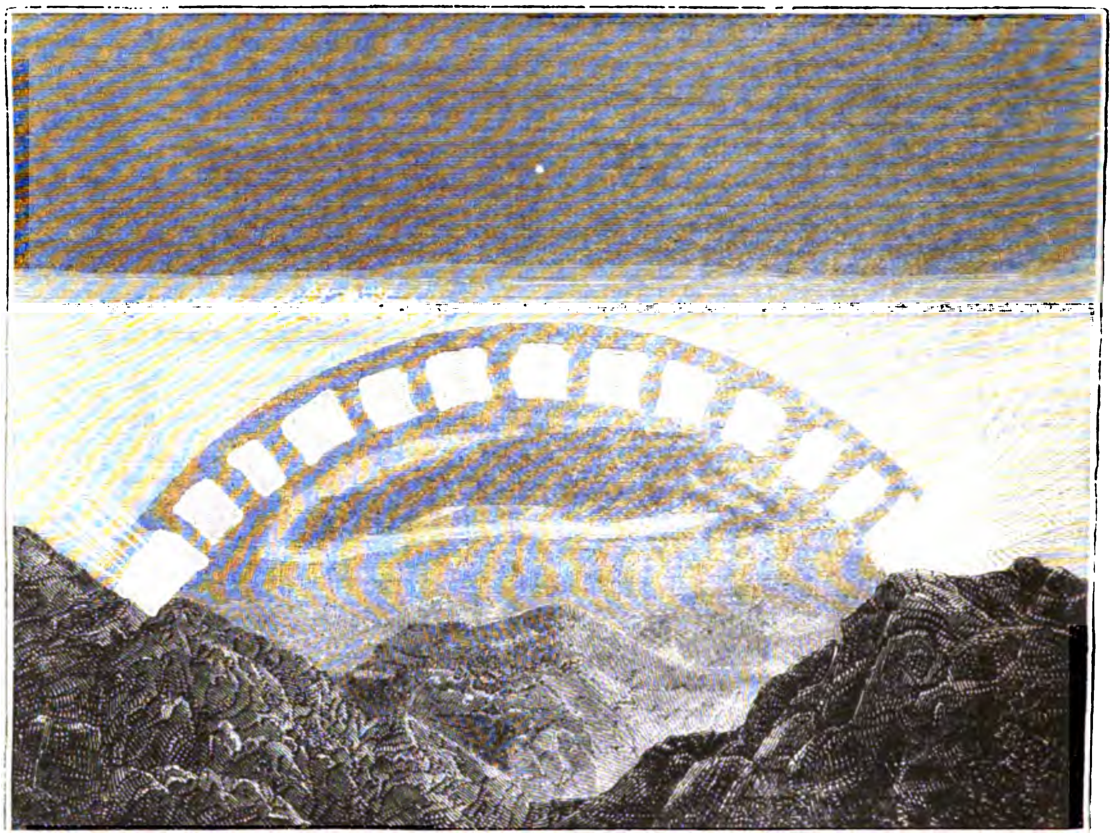


Fig. 2.—Aurora Borealis.

The two illustrations given above are selected, for their dissimilarity, from the work of M. de Mairau. *Fig.* 1 represents an aurora as seen at Breuillepont, in Normandy, nearly in the latitude of Paris, on September 26th, 1726. It consisted entirely of streams of light, without any darker meteor. *Fig.* 2 shows an aurora as observed at the same place, and which lasted for several minutes, on Oct. 19, 1726.

It has been a subject of some dispute whether any sound accompanies the development of the terrestrial light. The Greenland sledgers and Siberian fox-hunters are positive in their assertions that there is; and intelligent observers engaged in the Arctic magnetical and meteorological expeditions have recorded their evidence in the affirmative. On the other hand, Parry, Franklin, Richardson, and others state to having witnessed thousands of auroræ without perceiving any attendant sounds.

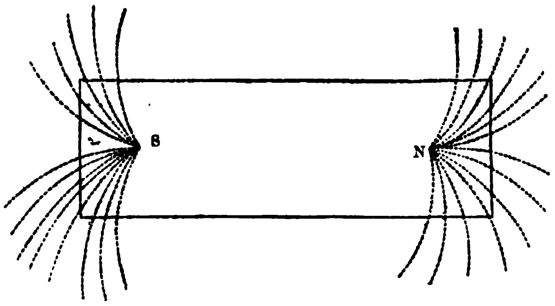
According to Dalton, the southern lights have been frequently seen in England; and the northern lights were seen in 45° S. lat. on January 14, 1831. Humboldt remarks, however, that "It is necessary to distinguish between the sphere of a simultaneous apparition of the phenomenon and the zone of the earth in which the phenomenon is displayed almost every night of the year. As each observer sees his own rainbow, so also, doubtless, does he see his own polar light. A great portion of the earth engenders the radiating light-phenomenon at the same time."

The intensity of the terrestrial light diminishes with the decrease of latitude, or, more strictly, with the decrease of magnetic latitude. In Iceland, Greenland, and on the banks of the Slave Lake, it appears at certain seasons every night. In Italy it is rare. On the shores of Siberia there appear to be "special regions of the northern lights."

There is great difficulty in determining the altitude of the terrestrial light, in consequence of the incessant oscillations of the luminous rays; so that the results of different observations "vary between several miles and three or four thousand feet." Moreover, it is probable that its altitude differs at different times.

Our observations and knowledge of the terrestrial light leads us to the important and interesting conclusion that our earth itself is luminous; and it is supposed that the degree of luminosity is a little greater than that of the moon in her first quarter. These considerations, compared with the observed fact that the planet Venus "glows occasionally with a proper phosphorescent gleam" in those parts which are not illuminated by the sun, lead us to inquire whether the moon and planets may not likewise be magnetic, thus keeping up a mutual influence between themselves and our earth.

Why the phenomenon of the terrestrial light should confine itself especially to the polar regions is readily explained on the supposition that it is a luminous discharge of superabundant magnetism; and since heat is destructive of magnetism, the magnetic intensity will be greater in the colder regions of the earth. [Terrestrial Magnetism.] An illustration of this may be given by taking a bar-magnet and dipping it in iron filings, when the filings will be found to arrange themselves near the poles of the magnet, presenting the appearance as shown in the following figures.



Aurora Borealis.

Aurora Australis.

Whether the magnetic condition of our earth has undergone any recent change we cannot say; but it is remarkable that we can find no very early accounts of the phenomenon we have been describing. It certainly appears to have been less frequent before the 18th century than it has been since. Torfœus, who wrote in 1706, relates that even in his own time the aurora was an object of terror in Iceland. For some time it was thought that there was no aurora australis, or terrestrial lights in the south; and though the fact is now well established, yet the earliest account we have of such an occurrence is given by Don Antonio Ulloa, who saw it at Cape Horn in 1745.

From the writings of Aristotle, Cicero, Pliny, and others, we read of appearances in the heavens which we conclude to have been auroræ, and which were viewed with the same superstition as comets.

For further information on this subject, the reader is referred to the writings of M. de Mairau (1754); Dalton; Humboldt's 'Cosmos;' Halley; Forbes; Expeditions of Parry, Franklin, Richardson, and Henderson; Kaemtz's 'Complete Course of Meteorology' (Lond., 1845); Reports of the British Association for the Advancement of Science; and the Philosophical Transactions of the Royal Society.

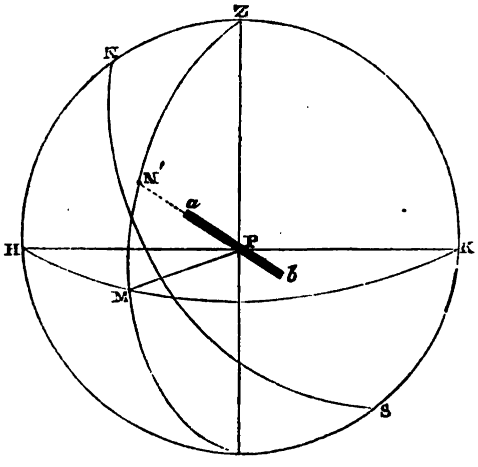
TERRESTRIAL MAGNETISM. If a magnetised bar of steel be suspended by a fine thread attached to its middle point, one extremity always points *nearly* to the north, the other end towards the south. Again, if a bar having a fine axle through its centre of gravity, and perpendicular to the axis of the bar, be placed with the axle resting on two highly polished surfaces, it will be found to make an angle with the horizon, and the magnitude of this angle will depend upon the place at which the experiment is made. The unknown influence which produces these phenomena is derived from the earth itself, and is called Terrestrial Magnetism. Hitherto no one has succeeded in reducing terrestrial magnetism to a theory, although various attempts have been made—and some with partial success. But the labours of mathematicians and observers have not been lost, for a mass of evidence on this important subject has been accumulated, which in due time will form the basis of a theory more wonderful even than that of gravitation, since it is not too much to assert that this unseen power, which for years has been known only, and thought of, for its practical utility, will one day prove to be the key to all the other phenomena in the universe. Terrestrial magnetism then is known by its effects upon the artificial magnet, and it is the province of the philosopher to observe, compare, and reduce these effects after they have been freed from all incidental and extraneous sources of error.

Until the year 1828, there were no systematic observations of magnetical phenomena; but since that time different countries—and especially our own—aided by their respective governments, have established observatories in all the most advantageous positions on the earth's surface; and sent out expeditions to the antipodes and places where a permanent observatory could not be maintained.

The object of these observations has been to determine the absolute value of what are called "the magnetic elements," and the periodical changes they undergo. The observations thus made, having been carefully corrected and reduced, are printed with such comments as seem necessary, and a description of the instruments and methods employed; and these enormous collections of facts are widely distributed throughout the scientific world under the title of Magnetical Observations.

There are three magnetic elements – namely, *the Intensity, the Inclination*, and *the Declination*.

If a magnetic needle be freely suspended from its centre of gravity, one extremity is drawn from the horizontal position by a force called the *Magnetic Intensity*, and the direction of this force is inclined to the horizon at an angle called the *inclination* or dip. These two elements appear to be independent of each other, and to vary with the position of the place of observation. Again, the needle does not point exactly north and south, but to points situated at some little distance from the poles of the earth—which points are called the magnetic poles. The angle between the meridian of the place of observation and the vertical circle in which the axis of the needle lies—that is, the vertical circle passing through the magnetic poles—is called the *Declination or Variation*. Thus, let *a b* represent a magnet freely suspended from its centre of gravity at any place P, whose zenith is Z. Let Z N H K represent the meridian of the place, H M K the horizon, Z N′ M the magnetic meridian, or the great circle in which the axis of the needle lies: N and N′ the true north pole and magnetic north pole respectively. Then the magnet *a b* is forced from a horizontal position into the position N′ *a b* by the intensity of the latter's magnetism. The angle N′ *a* P M is the inclination: and the angle between the circles Z N H, Z N′ M, which is measured by the angle H P M, is the declination.



The first object of the magnetic observer is to determine the absolute values of these magnetic elements, and then to trace the laws which regulate their hourly, daily, annual and secular changes.

It would be a difficult matter to construct an instrument which should at once give the absolute value of the *intensity*, and its periodical changes; but this object is readily attained by the application of the principle of the resolution of forces. For let F be the absolute value of the magnetic intensity, X and Y its horizontal and vertical components, θ the inclination or dip:

$$\text{Then}\quad F = X \sec\theta$$
$$\text{and}\quad Y = X \tan\theta$$

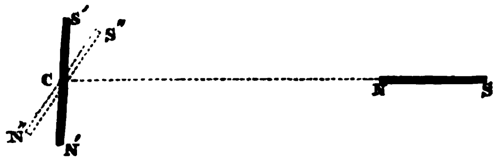
Now, as we shall see, there is no difficulty in determining the horizontal component X, and the inclination θ: hence, also, the vertical component Y and the total force F may be found.

Determination of the Horizontal Component of the Magnetic Force.—This element is obtained by a combination of two experiments made with an instrument called the Unifilar Magnetometer. In the first experiment, the time of vibration of a suspended magnet is observed. In the second experiment we observe the amount of deflection which the same magnet produces in a second magnet suspended by a single thread.

Let T denote the time of vibration of a suspended magnet, determined much in the same way as the oscillation of a pendulum might be observed, that is, by observing the time of the passing and repassing of a fixed point on the magnet past a vertical line placed in the focus of a fixed telescope. Let m be the magnetic moment of the bar, K its moment of inertia, then by the principles of Dynamics we have

$$m X = \frac{\pi^2 K}{T^2} \qquad (1)$$

Next let this same bar N S, be placed on a support in such a position that its axis lies in a straight line, passing through the centre of another magnet N′ S′, suspended by a single thread, and its direction perpendicular to the axis of the latter magnet. Then the magnet N S will deflect the magnet N′ S′ from its normal position into a position N″ S″. Let u denote this angle of deflection N′ C N″, r the distance between the centres of the two magnets. Then the condition of equilibrium will be given by the equation



$$\frac{m}{X} = \frac{1}{2} r^3 \sin u \qquad (2)$$

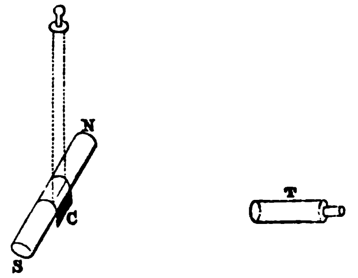
combining this with equation (1), we have

$$X = \frac{\pi}{T r} \cdot \sqrt{\frac{2 K}{r \sin u}} \text{ and } m = \frac{\pi r}{T} \sqrt{\tfrac{1}{2} r K \sin u}.$$

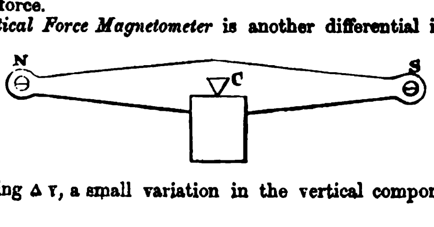
It is to be observed that the units of time, space, and mass referred to in these investigations, are by universal consent taken to be, a second, a foot, and a grain respectively.

But though we are thus enabled to determine the absolute value of this horizontal component X, and, therefore, also the changes it undergoes from time to time, yet it is not adapted to give those very minute changes which take place from hour to hour, and day to day. Such changes are called horary and diurnal variations; and the instruments by which they are observed are called differential instruments. The variation in the horizontal force is denoted by the symbol Δ X; and is observed by means of an instrument called a Bifilar Magnetometer.

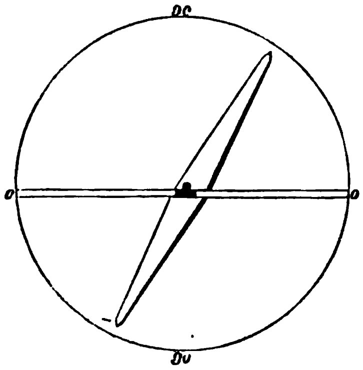
N S is a magnet suspended by two threads hanging from a screw which can be turned horizontally, so that the axis of the magnet can be constrained to assume a position approximately perpendicular to the magnetic meridian. Beneath the magnet, a graduated transparent scale, C, is suspended, and the readings of this scale are viewed by means of a telescope, T, whose axis is in the magnetic meridian. Now the horizontal force, X, evidently acts perpendicularly to the magnet, hence every change that it undergoes will cause the magnet to be deflected from its normal position. These deflections are read off by means of a vertical wire placed in the focus of the telescope; hence, having determined the change in the horizontal force which corresponds to one division of the scale, the reading of the scale at any time will show us the increase or decrease of the horizontal intensity—the zero reading of the scale corresponding to the normal value of the horizontal force.



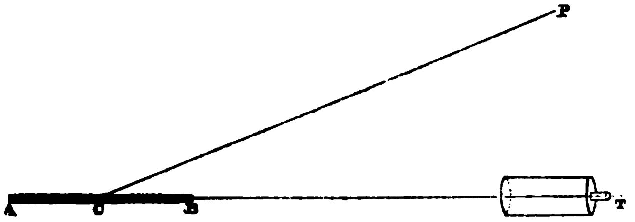
The Vertical Force Magnetometer is another differential instrument for observing Δ Y, a small variation in the vertical component Y. It consists of a light magnet, N S, with small holes at its extremities, across which fine threads are drawn in a horizontal position. Through the centre of the magnet is a knife-edge, C, perpendicular to the axis of the bar. This knife-edge is supported by two smooth agate planes, so as to free the motion of the magnet, as far as possible, from the effects of friction. The axis of the bar is placed in a position perpendicular to the magnetic meridian, thus rendering it independent of the inclination or dip. A small shifting weight is attached to the magnet, and is so adjusted as to bring the axis into a horizontal line for its normal position. Now it is evident that any change in the vertical force will deflect the bar from its horizontal position, and this deviation is viewed by means of two ordinary micrometers directed to the holes at N and S. The change in the vertical force which corresponds to any number of revolutions of the micrometer screw may be found by absolute determination; hence, also, the changes due to one or more divisions are known—the zero reading of the micrometer corresponding to the normal position of the axis of the magnet, for which position the absolute value of the vertical component Y has been carefully determined from the formula Y = X tan θ.



The Inclination or Dip is determined by means of a light magnet whose extremities taper to a point, and through the centre of which is a smooth cylindrical axle perpendicular to the plane in which the axis of the magnet moves. This circle rests on two smooth agate planes, and thus the magnet moves freely in a vertical circle whose rim is graduated through each of the four quadrants from 0° to 90°. When used, the instrument is adjusted so that the plane of the graduated circle, together with the axis of the magnet, is in the plane of the magnetic meridian, previously determined. The needle now assumes the *direction* of the magnetic force at the place of observation, and the reading of the graduated circle opposite to either extremity of the magnet indicates the *inclination* of the axis of the needle to the horizon. In practice, the means of both readings are taken, and several pairs of observations made. These and many other precautions are adopted in order to eliminate, as far as possible, the mechanical defects in the instrument, and errors of observation.



The Declination or Variation is determined by the following very simple process:—Let C T denote the magnetic meridian; C P, the astronomical meridian. Then the axis of a magnetic bar, A C B, suspended by a single thread attached to a point *above* its centre of gravity, will assume a horizontal position in the line C T; and a graduated glass scale being attached to the magnet, its zero-reading, which is taken to indicate the normal position of the magnet, is made to coincide with a vertical wire in the focus of the fixed telescope T. The angle P C T is the declination or inclination of the magnetic to the astronomical meridian, and is measured by a theodolite which is placed so that its axis is made to coincide with the line C T; and being then turned in azimuth until a distant object is seen which is *known* to be in the meridian of the place, the azimuthal angle thus measured is the normal declination.



This instrument, which is sometimes called the Unifilar Magnetometer, likewise serves to make differential observations of the declination; for there is no difficulty in determining the angular value of each division of the scale attached to the magnet: hence, if the vertical wire in the telescope coincides with the zero-reading of the scale at any specified time, when the needle is supposed to be in its normal position, any other reading will denote the angular deviation of the magnet from its original position, and therefore determines the corresponding variation of the magnetic meridian.

Such is a brief outline of the methods employed in determining the absolute value of the magnetic elements, and in watching the periodic changes they are constantly found to undergo. It is obviously beyond the limits of this article to enter into the numerous and elaborate details of the cautions which must be adopted by the observer; the methods employed to diminish the effects of instrumental errors; and the corrections which are applied to many of the observations to counteract the influence of temperature, which has the effect of changing the magnetic condition of the bars. For a more complete description of the magnetometers, and all the practical details necessary for observing and computing the observations, the reader is referred to the 'Instructions of the Royal Society to the Directors of Magnetical and Meteorological Observatories.'

We now proceed to notice some of the most prominent phenomena in connection with terrestrial magnetism. It has been already stated that the magnetic elements are subject to periodic changes. These changes are generally slow, and exhibit a certain amount of regularity, though the laws which govern them have not yet been arrived at. One of the most apparent, perhaps, of these fluctuations is seen in the declination magnet, that end which is towards the north moving slowly westward during the forenoon, and returning to its normal position about ten in the evening. It then moves towards the east, and returns to its former position about ten in the morning. These changes evidently establish the fact that the motion of the magnetic meridian is in some way connected with that of the sun. The other magnetic elements also undergo similar though less striking changes; and it is to be observed that each succeeding day will not show exactly the same set of hourly variations as its predecessor, nor are the observations of one year identical with those of another.

But, besides these known periodical fluctuations, which past experience teaches us to look for from time to time, there are sudden and unaccountable disturbances in the magnetic elements arising, it is supposed, from some sudden derangement in the magnetic condition of the earth.

This phenomenon exhibits itself in a sudden and sometimes violent agitation of the suspended magnets. During these magnetic storms, as they are called, the magnets oscillate to and fro, sometimes slowly and regularly, at other times with such rapidity that the observer is unable to note the time or arc of the vibration; and often the scale by which the position of the magnet is viewed is completely carried out of the field of the telescope. On some occasions the magnet seems to be acted upon by a succession of rapid jerks; at other times a quivering motion is detected, so much so as to render the scale indistinct. These unusual disturbances, the particulars of which have, when observed, been carefully recorded at the different observatories, do not appear to have electricity as their origin, since they do not necessarily take place during an electric storm. The most remarkable feature attending them is the fact that simultaneous disturbances of the magnets at different places are found to take place during a display of the aurora borealis [TERRESTRIAL LIGHT], thus connecting that phenomenon with terrestrial magnetism.

Some philosophers have supposed that earthquakes are accompanied by magnetic disturbances; but the great Humboldt doubts this, though he was startled by observing, during the violent earthquake of Cumana in 1799, "that the dip was diminished by 48′."

Magnetic phenomena appear to be immediately connected with meteorological changes. Hence it is that meteorology forms an important part of the work of a magnetic observatory; and observations of the thermometer, barometer, wind, and weather are made simultaneously with those of the magnets. Violent gales, sudden changes of temperature, and rapid barometric fluctuations are generally accompanied by magnetic disturbances.

Each place on the earth's surface has its own distinct magnetic elements. We have already stated that the freely suspended needle does not point exactly north and south, but to two points near the terrestrial poles. These points are called the magnetic poles. When the meridian of any place likewise passes through the magnetic poles, it is evident that the magnetic meridian coincides with the terrestrial, and there is no declination or variation; and the locus of all such places is called "the line of no variation." Again, at places near the equator, the dip needle is horizontal, and the locus of all such places, which locus does not coincide with the equator, nor is it an exact circle, is called the "line of no dip." As we proceed towards either of the terrestrial poles, the needle becomes more and more inclined to the horizon, until we reach the magnetic poles, where it assumes a vertical position.

Likewise, also, the absolute intensity of the magnetic force depends upon locality. It appears to increase as we proceed from the equator to the poles, and the curves which pass through all those places where the intensity is the same, are called "isodynamic lines." These lines do not coincide exactly with parallels of latitude, nor with lines of *equal dip*. According to the most recent determination, the north magnetic pole is situated very nearly in latitude 70° 5′, and west longitude 96° 47′. Some have supposed the existence of two magnetic poles in each hemisphere, the position of the second northern pole being in Siberia, about 60° north latitude, and 102° east longitude. The positions which have been assigned to the southern poles are a little to the south of Australia, and south-south-east of New Zealand. This hypothesis, however, must be adopted with caution.

The following is a comparative view of the value of the magnetic elements at some places where they have been determined with the greatest accuracy:—

	Declination.	Dip.	Total Force.
Greenwich	22° 51′ west	68° 59′	10·4
Toronto	1° 27′ ,,	75° 17′	13·9
St. Helena . . .	22° 46′ ,,	21° 37′	6·3
Cape of Good Hope . .	29° 8′ ,,	53° 35′	7·6
Hobart Town . . .	9° 47′ east	70° 36′	13·5

The causes of terrestrial magnetism have still to be developed. Various theories have been from time to time proposed, some of which have indeed successfully accounted for a few of the known magnetical phenomena, but fail under the tests which science and observation supply us with. The elaborate theory founded on the supposition that the earth is an actual magnet, is overturned by the discoveries of Faraday, Arago, and other philosophers. Although there does not appear to be a simultaneous occurrence of magnetic and electric storms, yet there can be little doubt of the connection between these phenomena, even if magnetism be not "one of the numerous forms under which electricity developes itself." The experiments of Faraday and Oersted have shown, not only that "electricity induces magnetism in the vicinity of the body which conducts it," but that "free magnetism gives rise to electricity." Assuming, what is highly probable, that the interior of the earth is a mass of liquid fire, then the idea of a magnetic nucleus in the earth must be abandoned, for it is found by experiment, that the magnetism of a body is destroyed when it reaches a white heat. It is, therefore, the earth's crust only which we may assume to be the seat of magnetic currents. That such currents do exist, is by no means improbable, and experiments seem to show that they are immediately excited by unequal distribution of heat. If we regard the aurora borealis [TERRESTRIAL LIGHT] as a luminous discharge of superabundant magnetism, we can understand how this phenomenon should be confined to the vicinity of the colder regions, where the earth's surface is least heated, and the magnetic intensity, therefore, the greatest. No less than 146 years ago, Halley ('Philosophical Transactions') had boldly ventured to conjecture, that the terrestrial light was a magnetic phenomenon. But when the fact became established, that the aurora indicated its appearance by the disturbed state of the magnet in all parts of the globe, and the brilliant discovery was made by Faraday, that light could be evolved by magnetic power, then a passing conjecture acquired a degree of probability amounting almost to certainty.

It is curious that Galileo was inclined to account for the parallel direction of the earth's axis, on the supposition of a distant magnetic point of attraction in space. Without entering upon the consideration of a question which we usually refer to dynamical principles, yet it is pretty certain from recent observations, that both the sun and moon do exert an influence upon the magnet, and philosophers are strongly disposed to connect the variable phenomenon of the spots on the sun with the magnetic condition of our earth.

For further and more complete information on this subject, and subjects closely allied to it, the reader is referred to the following authorities: Humboldt's 'Cosmos,' Sabine's translation; Somerville's 'Connection of the Physical Sciences;' Young's 'Lectures on Natural Philosophy;' Brewster's 'Magnetism;' Faraday's 'Researches;' 'Reports of the British Association for the Advancement of Science, on Magnetism and Meteorology;' 'Philosophical Transactions' of the Royal Society; Barlow on 'Magnetic Attractions;' 'Annuaire Magnétique,' St. Petersburg, 1836; Gauss, on the 'General Theory of Terrestrial Magnetism,' in Taylor's 'Scientific Memoirs,' August, 1839; Gauss and Weber's 'Magnetic Atlas,' Leipzic, 1840; 'Report of the Committee of Physics of the Royal Society;' 'Magnetical and Meteorological Instructions of the Royal Society;' 'Magnetical and Meteorological Observations made at different Observatories, and printed by direction of the British and Foreign Governments, and the Honourable East India Company.'

Amongst those who have enriched this science by their investigations and observations, we may make especial mention of General Sabine, to whom, in conjunction with Sir John Herschel, and the present Astronomer Royal, is due the establishment of magnetic observatories and well organised expeditions, which have furnished upwards of 2,000,000 of observations in the course of three years, and who has, ever since the year 1819, devoted himself to the cause of terrestrial magnetism.

But terrestrial magnetism it still in its infancy; much remains to be done; and so simple and inexpensive are the methods and instruments of observation, that many would find a delightful and profitable amusement in the study—especially in the observance of magnetic storms—and thus contribute their mite towards the discovery of "the great ocean of truth."

TERRESTRIAL TEMPERATURE, DISTRIBUTION OF. The subject of the earth's temperature has already been treated of at some length under different headings. Generally, it was shown under CLIMATE and METEOROLOGY, that the temperature of the air in any region depends on the inclination of the sun's rays to the surface of the earth in that region; on geographical position and physical conformation, the distribution of land and water, the state of the countries from which come the prevailing winds, the vicinity of the sea, the elevation of the land, the electrical state of the atmosphere, and numerous other circumstances and phenomena. Under Refrigeration of the Globe, the question of the influence of the proper, or internal, heat of the globe on its superficial temperature is examined. The condition and properties of the Atmosphere are investigated under that title. Under Snow, Perennial, the decrement of temperature on ascending into the atmosphere is noticed. Under Sea, the temperature of the ocean is considered. Whilst the effects of oceanic currents, glaciers, deserts, &c., are treated under those heads either in the present division, or in the Natural History and Geographical Divisions of this Cyclopædia. The important subject of Terrestrial Magnetism is reserved for a distinct article. Here it only remains to speak of some of those general deductions of recent investigators in climatology which have not been specifically mentioned; and especially have we to do so in reference to isothermal lines, or lines of equal temperature, for an account of which, reference has been made to this article from Isothermal Lines; and to the temperature of the atmosphere over the sea, a branch of the subject which has been referred to the present article from Sea.

In the primitive condition of the earth, when the globe was a fluid mass, or in remote geological periods, when its central fluid mass was covered with a comparatively homogeneous crust, the effect of the radiation of its heat on the superficial temperature must, as Mr. Hopkins has shown, have been almost unlimited. But as by this radiation it would continue to part with heat till the superficial temperature approximated to that of the circumambient space, unless the radiation were compensated by the generation of heat on the surface, which is known not to have been the case, it must necessarily happen at some indefinite time (it has been shown to require many millions of years), that the internal heat of the globe would cease to exert any appreciable influence on its superficial temperature. And this is what has now very nearly come to pass [Refrigeration of the Globe]; this influence, according to the calculations of Mr. Hopkins, being now reduced to less than the twentieth of a degree Fahrenheit. In fact, whilst volcanoes, thermal springs, borings for artesian wells, the continuous increase of temperature in descending deep mines, and other phenomena, afford irrefragable evidence of the higher temperature of the interior of the globe, it is as clearly seen that for a short distance from the surface the temperature of the earth is dependent on external heat and moisture, and varies with the seasons of the year and the hours of the day, whilst at a greater, but still small depth—which varies according to the latitude of the place, and the conducting power of the rock, but nowhere probably exceeds 100 feet—a point is reached at which there is no sensible change of temperature, and which has accordingly been designated the *Invariable Stratum*. The present influence of the internal heat of the globe, although almost inappreciable, may, however, acording to Dove, be regarded as constant; "lessening the extremes, but not affecting the periods of the variations of temperature at the surface."

When the influence of the internal heat ceased to be paramount on the surface, changes of temperature must have been in a large measure due to the altered conditions of land and water—the elevation of mountain regions, the subsidence of extensive areas, and the consequent changes of oceanic currents—to glacial action, &c.: circumstances of which the results are clearly traceable in the animal and vegetable remains preserved in the various strata which compose the crust of the earth, and some of which (as notably in the case of the Gulf Stream and the Arctic Current) are shown by the remarkable inflections of isothermal lines to be distinctly operating now. (Hopkins, 'Trans. of Geol. Soc.,' and 'Cambridge Phil. Trans.')

In considering the present temperature of the earth, the sun must be regarded as the only source of heat and the ultimate cause of all climatic change, and hence we arrive at the possibility of ascertaining, amidst all casual fluctuations, a regularly recurring periodicity, annual as well as diurnal, for every variety of geographical position. The bearing of this periodicity on a theory of the general distribution of heat appears to have been first distinctly observed by Kirwan, who (in vol. viii. of the Irish 'Transactions') constructed a table of monthly temperatures for all parallels of latitude between 10° and 80°. Before the difference of temperature on the same parallel of latitude in the old and new continents was known or regarded, a simple formula was thought sufficient to express the temperature at any parallel of terrestrial latitude. The celebrated Tobias Mayer, from such mean temperatures as had in his time been observed, found that the temperature t (on Fahrenheit's scale) at any place might be represented by $\text{T} - 52^\circ \sin.^2 \text{L}$, where T is the mean temperature at the equator, and L the geographical latitude of the place; and in 1819 M. Daubuisson ('Traité de Géognosie') proposed the more accurate formula $t = 27^\circ \cos.^2 \text{L}$ (centigrade scale); which being adapted to Fahrenheit's scale, considering the mean temperature at the equator to be 81°, becomes $32^\circ + 49^\circ \cos.^2 \text{L}$. This formula has been found to serve for temperatures in Europe as far north as the latitude of 60°; but beyond that parallel it is useless, as it supposes the temperature at the geographical pole to be 32°, which is much too high.

It was however reserved for Humboldt to determine (1817) from the registers of observed temperatures in Europe, and from the numerous observations made by himself and other travellers in different regions of the world, the constancy of the mean annual temperature of places, and to "connect graphically by lines those points where accurate observations indicated equality of mean periodic temperature." Those lines (or curves supposed to be traced on the surface of the earth) which connect the places where the mean annual temperature is the same he called *Isothermal lines*. In order to ascertain with the utmost possible precision the mean temperature of any place from the tables there kept, Humboldt divided the sum of all the temperatures observed in each day at intervals of one hour by the number of observations; and the sum of all these mean daily temperatures being divided by 365, gave the mean annual temperature. And in determining the series of points for his lines of equal temperature, when there existed no observations on which he could depend, he interpolated the temperature and geographical position between the values of those elements at two or more places where they were well known.

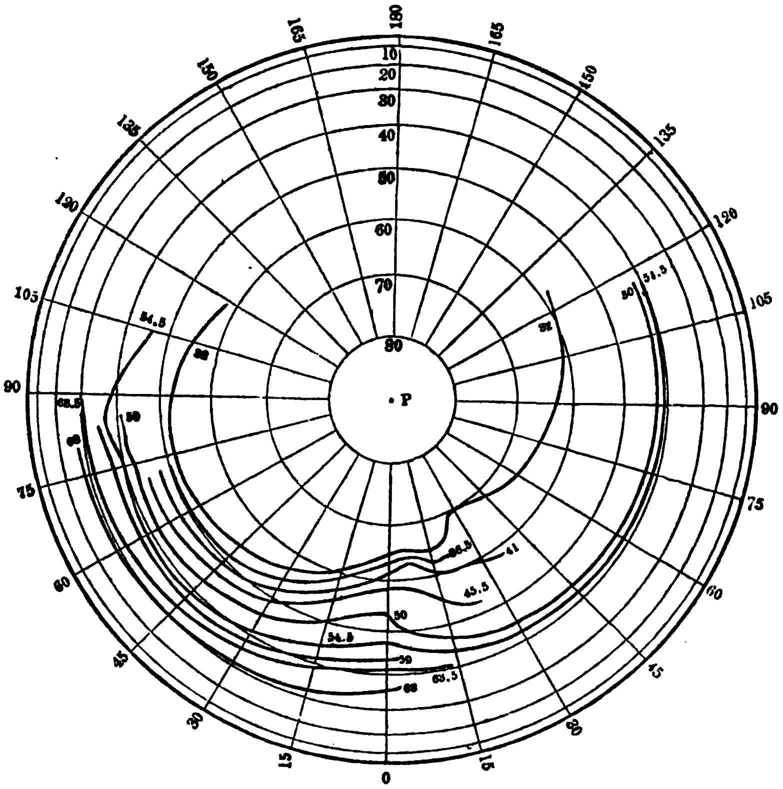
The diagram on next page represents an orthographical projection, on the plane of the equator, of the principal meridians and parallels of latitude in the northern hemisphere of the earth; and the strongly marked curves represent the nine isothermal lines whose forms were determined by Humboldt. Their distances from one another are such as correspond on the earth to a change of mean annual temperature equal to 2·5 degrees of the centigrade thermometer (4·5° of Fahr.), and the most northern curve is that on which the mean temperature is expressed by zero on the former, or 32° on the latter scale. The number on each curve in the diagram expresses, according to Fahrenheit's thermometer, the mean annual temperature, at the level of the sea, of all the places through which the curve passes. The centre P represents the pole of the earth, and the longitudes of the meridian lines are numbered eastward and westward from the meridian of Greenwich.

The isothermal line of 32° passes about 4° southward of Nain, a Moravian settlement on the coast of Labrador; and under the influence of the gulf stream, makes a remarkable inflexion, ascending as high as North Cape in Lapland, where it abruptly returns southward, and attains its lowest limit in the eastern parts of Asia, about 50° N. lat. Proceeding westward from Labrador the curve crosses the lower extremity of Hudson's Bay, from whence it again tends northwards to the Great Slave Lake, reaching its northern maximum in about 70° N. lat. The positions of the other curves seem to be affected in a greater or less measure by the same influences as act upon the curve just mentioned. In their progress from the western coast of Europe to the eastern coast of America they incline towards the terrestrial equator, yet so that the southern curves approach near to parallelism with that great circle of the earth. Within the territory of the United States they assume a form which is convex to the equator, and farther west they appear to reascend towards the north. In the isothermal lines of 50° and 60° westward, and those of 40° to 10° eastward of the meridian of Greenwich the curves have their convexities turned northwards; and farther eastward they descend towards the equator. The isothermal line of 54·5° is one that has been traced nearly round the earth: commencing at the mouth of the Columbia, on the western coast of North America, it passes south of Council Bluffs, and near the city of Washington with its convexity towards the south; and after crossing the Atlantic it runs between Paris and Bordeaux, from whence it continues to a point a little north of the city of Pekin, where it is again convex towards the equator.

But it must be remembered that in every country the mean temperature varies with the height of the place above the level of the sea; and Humboldt, from observations made as well on the Cordilleras as in Europe, having determined that at every 343 feet the mean temperature of the air is diminished by a quantity equal to that diminution which is consequent on an augmentation of latitude equal to one degree, calculated a table of the corrections which should be made in the curvatures of the isothermal lines at the level of the sea, in order to obtain the forms of those which appertain to points at any given elevation, but this calculation, as pointed out under Climate (col. 968) does not hold with strict accuracy for places situated without the tropics.

The differences between the mean summer and mean winter temperatures Humboldt found to be very considerable at places whose mean annual temperature is the same; and these differences are not equal in the Old and New Continent. On the isothermal line of 32° in Europe, that difference proved to be equal to 39·6°, and in America to 54°; and on the isothermal line of 68° the differences were respectively 21·6° and 27°. He also remarked that the differences between summer and winter are least near the northern, and greatest near the southern bends of the curves. To indicate these variations, Humboldt laid down other lines. The curves formed by connecting, on the isothermal lines, points at which the mean temperature of summer is the same he called *Isotheral* lines; and those formed by connecting points at which the mean winter temperature is the same *Isocheimal* lines: both these systems of lines he found to deviate more than the isothermal lines from the parallels of terrestrial latitude.

Humboldt, in the first volume of his 'Cosmos,' expressed a hope that not only a clearer insight had thus been gained into the distribution of heat in the atmosphere, but that this "system of Isothermal, Isotheral, and Isocheimal lines, if gradually perfected by the united efforts of investigators, may prove one of the chief foundations of a



Comparative Climatology." In this hope he was no doubt fully justified, but one of the most profound of his followers, Professor Dove of Berlin, was led to the conclusion, as the result of the tabulation of an enormous mass of observations, ('Meteorologische Untersuchungen,' Berlin, 1837; 'Temperaturtafeln,' 1849; 'Die Verbreitung der Wärme auf der Oberfläche der Erde,' 2nd edit., 1853; 'Klimatologische Beiträge,' 1857, &c.,) that it was necessary, in order to understand the true climate of a place, to carry this system of lines of equal temperatures much beyond those of annual and semi-annual periods, there being between places of nearly the same mean annual temperature sometimes very remarkable monthly variations, and to which are due the most marked differences in the general character of the climate and natural productions of the respective places. Dove in short concluded that it was necessary to have a complete series of *Monthly Isothermals,*—a name he judiciously adopted for the curves connecting places having equal temperatures in the same month, instead of carrying further the terminology of Isotheral and Isocheimal: the lines of equal annual temperatures he proposed to call *Yearly Isothermals* instead of simply *isothermals* with Humboldt. Of these Monthly Isothermals, Dove has given separate maps on the equatorial projection for each month, and combined polar and equatorial maps for January and July. He has also carefully observed and laid down in a series of maps the monthly thermal anomalies, uniting them by lines which he terms *Isabnormals.* Indeed his maps, tables, and memoirs altogether present a surprising mass of information on this branch of science, with the greatest precision and clearness. In his essay on 'The Distribution of Heat over the Surface of the Globe,' translated for the British Association, he arranges the different Monthly Isothermals which he has established into four classes :—

"1. Isothermals which are always found in pairs, intersecting both hemispheres : this class includes all between 32° and 77° Fahr.

"2. Isothermals which are sometimes single and sometimes in pairs, that is, sometimes intersecting one or other hemisphere only, and sometimes both: to this class belong many of the isothermals below the freezing point, and some of those of highest temperature which do not pass through all meridians, for example, 81°·5 Fahr.

"3. Isothermals which always occur singly (or in one hemisphere only), at a particular season, not touching it in other parts of the year: to this class belong the isothermals of lowest, and also those of highest temperature (40° and 90°·5 Fahr.) which are only developed at particular seasons, and enclose detached spaces.

"4. Lastly, the isolated patches of highest temperature which are developed at particular places in the torrid zone, without passing through all meridians, and are enclosed by isothermals that fork, that is, divide into two branches, (79°·25, and 81°·5 Fahr.)."

Having thus briefly indicated the character of the several Isothermal lines, we refer back to the articles CLIMATE and METEOROLOGY, where, and in the connected articles there referred to, the circumstances which appear chiefly to regulate the temperature of the earth will be found discussed at length; also various details illustrative of the temperature of different parts of the earth's surface; together with tables of the mean temperatures in different latitudes, as well as formulæ expressive of the most important general results. We shall in this place merely add that Dove has deduced as the result of his tabulation of innumerable observations, that the mean annual temperature at the surface of the earth is in January 48°·9 Fahr. in the Northern, and 59°·5 in the Southern hemisphere, giving a mean of 54°·2 for the whole earth; while in July it is 70°·9 Fahr. in the Northern and 53°·6 in the Southern hemisphere, or 62°·3 for the whole earth, thus showing an increase of 8° Fahr. from January to July. Again if we take "the mean between the temperatures of January and July for the northern and southern hemispheres respectively, we find for the northern hemisphere 59°·9, and for the southern 56°·5 Fahr., being 58°·2 for the whole earth." Further he has found that in all seasons of the year there is encompassing the whole earth a zone having a temperature above 77° Fahr.

The following tables, by Dove, show the mean annual temperatures at different degrees of latitude in the two hemispheres, and the mean annual decrease of temperature from the equatorial to the polar regions :—

MEAN ANNUAL TEMPERATURE OF THE NORTHERN AND SOUTHERN HEMISPHERES.

Latitude.	Northern Hemisphere.	Southern Hemisphere.	Difference.	Mean.
0°	79°·7	79°·8	0°·1	79°·8
10°	79·9	78·8	2·1	79·0
20°	77·5	74·1	3·4	75·8
30°	69·8	66·9	2·9	68·3
40°	56·5	54·6	1·9	55·6

DECREASE OF TEMPERATURE FOR THE ENTIRE EARTH.

Latitude . . .	0°—10°	10°—20°	20°—30°	30°—40°	0°—40°
Northern hemisphere .	—0°·2	2°·5	7°·7	13°·3	24°·3
Southern hemisphere .	1·8	3·8	7·2	12·4	25·2
Earth	0·8	3·2	7·4	12·8	24·8

We now turn to the distribution of the atmosphere over the sea. [SEA.] It is a well established fact, that places near the sea have a more uniform climate than those which are at great distances from it, though in the same latitude. Inland places experience a much greater degree both of heat and cold than places on the coast, and the difference between these degrees of heat and of cold increases with the distance of the place from the sea. This phenomenon has been variously explained. The explanation is now pretty clear, since it has been proved by observation that the temperature of the air over the sea is less subject to changes than, or rather does not undergo such great changes as, that of the air which is over the land. But as the temperature of countries situated between the tropics is not subject to so great changes as that of countries in the temperate zone, and these again are less affected by them than the frigid zone, so it is found to be the case on the sea also. Beginning with the smallest natural division of time, the day, it is found that between the tropics the difference of temperature within 24 hours seldom exceeds 2 degrees of Fahrenheit, and rarely amounts to more than 3 degrees. The following table, from Meyen's 'Reise um die Welt,' shows the changes of temperature on the sea during 24 hours between the tropics :—

1830, October 25; lat. 14° 17′ N., long. 26° 37′ W.

1^h.	79·88°	9^h.	80·96°	5^h.	81·14°
2	80·06	10	80·96	6	81·14
3	80·06	11	80·96	7	81·14
4	80·06	12	80·96	8	80·96
5	79·88	1	81·14	9	80·78
6	79·70	2	81·50	10	80·96
7	79·70	3	81·96	11	80·24
8	79·70	4	81·68	12	80·24

The difference between the highest and lowest temperature is only 2·26°. The mean temperature of the day is 80·65°, which is only 0·95° above the lowest and 1·31° below the highest temperature. It must, however, be remembered, that during the day to which these observations refer, the vessel on which they were made advanced through nearly 1¼ degrees of latitude, which of course must have had some effect on the temperature.

There is a greater difference in the daily temperature of the sea within the temperate zone : though when compared with the changes which occur in any place situated in the same zone, but not immediately on the shores of the sea, it will be found considerably less than in the latter. The following table from Berghaus, of the changes on the sea, may be compared with the changes in the temperature of London in the middle of March :—

March 16; lat. 31° 0′ N., long. 64° 11′ W.

1^h.	43·7°	9^h.	44·6°	5^h.	43·7°
2	43·7	10	44·6	6	42·8
3	43·7	11	44·6	7	41·0
4	43·7	12	44·6	8	41·0
5	44·6	1	46·4	9	41·0
6	44·6	2	45·5	10	41·9
7	44·6	3	44·6	11	41·9
8	44·6	4	43·7	12	42·8

The difference between the maximum and minimum of the daily temperature in this table amounts to 5·4°, and the mean temperature of the day is 43·7°. The maximum is 2·7° above the mean temperature, and the minimum is 2·7° below it.

We come to the same conclusion that the temperature of the air over the sea is subject to less considerable changes than that which surrounds the land, when we compare the changes that occur during the seasons. Looking at the difference of temperature between the hottest and coldest season in Berghaus's tables, we find that this difference is much greater, and at the same time more irregular, in the northern than in the southern hemisphere. But this seems to be due, in a great measure, to the influence of the Arctic current and to the difference between the winter and summer temperature, owing to the presence of vast masses of ice, which during winter extend as far south as 40° N. lat.; between 55° and 25° the increase of the mean temperature of the spring is tolerably regular, rising from 4¼° to 5° for every 5 degrees of latitude. The other irregularities are evidently produced by a greater increase of the heat in summer. The mean temperature of the summer increases pretty regularly between 55° and 45° by from 2 to 4 degrees for every 5 degrees of latitude. But between 45° and 40° it rises suddenly to more than 6 degrees. This sudden rise is, no doubt, produced by the warm vapours arising from the Gulf-stream [ATLANTIC OCEAN, in GEOG. DIV.], which in these parts runs across the Atlantic. Another rise of more than 6 degrees occurs between 40° and 35° N. lat. The air of the Sahara, when raised to the highest degree of heat by the continuance of the sun near the northern tropic, seems to affect the mean temperature of the summer between 40° and 15°, and to raise it nearly to the mean temperature of that season under the equator. The effect of this heated air has been distinctly traced for an immense distance, we may, however, suppose that it ceases near Cape Verde; but the effects of another phenomenon begin to operate. The region of calms [CALMS] frequently extends in summer to 12° and 13° N. lat. Of these three agents, the heated air of the Sahara seems to have the greatest effect in raising the summer temperature of the Atlantic. Again, the fact that most of the isothermal lines run in a north-eastward direction from the western side of the Atlantic towards the eastern, and then bend downwards towards the south, indicates, as Maury remarks, the presence along the African shores in the North Atlantic of a large volume of cooler waters, the return current of the Gulf stream.

When two elements, such as air and water, approach each other, there can be no great difference in their temperature. Still there must be some difference, as the air is the better conductor of heat, and the water, as a more dense body, is capable of retaining it for a greater length of time. Many observations have been made for the purpose of establishing this difference more precisely. It has been found that the temperature of both is subject to regular changes during the day, but that the air attains its highest temperature about two o'clock, whilst the sea attains its highest temperature in some parts at three o'clock, in others not before four o'clock. Further, it appears that the temperature of the air is greater shortly before and after noon, and that of the sea about midnight; but in the morning and evening the two elements have nearly the same temperature. On the land, again, the coldest and hottest months are February and August, but on the sea the vast amount of observations collected by Maury ('Physical Geog. and Meteorology of the Sea,' ch. xvii., ed. 1860), show distinctly that the extremes occur in March and September. It has further been found, that "at sea the climatic conditions of the land are reversed, for the coldest side of the ocean is next the warmest side of the continent, and *vice versâ*" (Maury), conditions, however, which a little reflection will render readily comprehensible. When these slight changes are excluded, it is found that the difference of temperature in both elements is inconsiderable, but differs in different latitudes.

The great preponderance of water in the southern hemisphere is, as Dove has pointed out, the prime cause of the southern hemisphere being a region of warm winters and cool summers, while the northern is characterised by cool winters and hot summers; an increasing quantity of the sun's heat becoming latent, as, in passing from north declination and entering the southern signs, it is employed in evaporating an increasing quantity of aqueous vapour. And, as he observes, "the mild winter of the southern hemisphere, plus the contemporaneous hot summer of the northern, necessarily gives a higher sum of temperature than the cool summer of the southern plus the cold winter of the northern hemisphere." These relations, he suggests, appear to furnish, in the periodical conversion of the aqueous vapour into a liquid form, the motive power in the machinery of the general atmosphere of the earth. "The unequal distribution of land and sea in the northern and southern hemispheres appears to supply an effectual provision, from whence it necessarily follows that the aqueous vapour, which from the autumnal to the vernal equinox is developed to an immense extent over the southern hemisphere, returns to the earth in the other half of the year in the form of rain or snow. And thus the wonderful march of the most powerful steam-engine with which we are acquainted, the atmosphere, appears to be permanently regulated. . . . It is probable that the northern hemisphere may be regarded, comparatively speaking and to a considerable degree, as the condenser in this great steam-engine, and the southern hemisphere as its water-reservoir; that the quantity of rain which falls in the northern hemisphere is therefore considerably greater than that which falls in the southern hemisphere; and that one reason of the higher temperature of the northern hemisphere is, that the large quantity of heat which becomes latent in the southern hemisphere in the formation of aqueous vapour is set free in the northern in great falls of rain and snow." ('Essay on Distribution of Heat,' p. 26, Eng. translation.)

TERRIER, from the French word *terrier*, a land-book, a register or survey of lands. Those best known in this country are the ecclesiastical terriers made under the provisions of the 87th canon. They consist of a detail of the temporal possessions of the church in the parish. They ought to be signed by the parson, and are sometimes also signed by the churchwardens and some of the substantial inhabitants of the parish. Their proper place of custody is the bishop's or archdeacon's registry: a copy also is frequently placed in the parish chest. If a terrier is proved to be produced from the proper custody, and therefore may be presumed to be genuine, it is in all instances evidence as against the parson. And in those instances where it has been signed by churchwardens elected by the parish or by the inhabitants, it is also evidence as against the inhabitants generally; even against those occupying lands other than the lands occupied by the inhabitants who signed it. The questions in respect of which a terrier is generally employed as evidence are those relating to the glebe, tithes, a modus, &c.

TERSTEARIN or **TRISTEARIN**. [STEARIC ACID.]

TERUNCIUS. [AS.]

TESSELATED PAVEMENTS. [TILES; PAVEMENTS.]

TE'SSERA, a small cube or square resembling our dice, which was used by the ancients for various purposes, and accordingly it consisted of different materials, as marble, precious stones, ivory, glass, wood, or mother-of-pearl. Such small tesseræ of different colours were used to form the mosaic floors, or pavements in houses [MOSAICS], which were hence called tesselata pavimenta. (Sueton., 'Cæsar,' 46.) The same kinds of cubes, usually made of ivory, bone, or hard wood, and marked on all their six sides, were used by the ancients as dice in games of hazard, just as in our times. In the earlier times three dice were used in a game, but afterwards only two.

The word tessera was also employed to signify any token which was given to persons by which they might recognise one another. In this case however the tesseræ were probably small tablets marked with certain signs. Thus we find mention of a *tessera hospitalis*, which strangers when forming a connection of hospitality gave to one another, that they or their children might afterwards recognise one another, and it appears that a tessera in this case was marked with the figure of Jupiter hospitalis. (Plautus, 'Poenul.,' v. 1, 25; 2, 87, &c.) Tesseræ frumentariæ, or nummariæ, were occasionally given at Rome to the poor to serve as a token or ticket, on the presentation of which they received a certain amount of corn or money. (Sueton., 'Aug.,' 40; 'Nero,' 11.) The Roman soldiers also, before they commenced a battle, received a tessera containing the watchword by which they recognised their comrades, and were enabled to distinguish them from strangers. (Virgil, 'Æn.,' vii. 637, with the note of Servius.)

TEST PAPERS. Strips of paper impregnated with certain reagents as litmus or turmeric, and used by chemists for detecting the presence of certain bodies. [Tests, Chemical.]

TESTAMENT. [Will.]

TESTAMENT, OLD AND NEW. Some critical disputes have arisen respecting the meaning of the word *Testament*, as applied to the Canonical Scriptures. These, under the name of the two Testaments, comprise the revelations of God to man, which, being imparted under two principal conditions—the Law and the Gospel—are divided into two corresponding classes. The word translated by *covenant* is the Hebrew *berith*, so used in the first division of the sacred writings, and rendered in the latter by *diatheke* (διαθηκη). But a further notion than that conveyed by the Hebrew is contained in the Greek term (and which belongs also to the ecclesiastical Latin one, *Testamentum*, the original of the ordinary designation of the two portions of the Scriptures, the Old and New *Testaments*). No more appropriate designation than that of the New Testament can be applied to the second portion. Its application to the books of the Old was defended by St. Jerome (among other authorities of equal weight), on the ground that "Testamentum non voluntatem defunctorum sonat, sed pactum viventium." The books of the Old and New Testament are noticed at length under their respective titles; their inspiration is treated of under Revelation: see also Scriptures; Bible; Apocrypha, &c.

TESTAMENTS OF THE TWELVE PATRIARCHS, a Greek work which professes to contain the last words of the twelve patriarchs, the sons of Jacob, but which is considered to be undoubtedly spurious by all writers except Whiston, who accepts it as a part of the canon of the Old Testament; but no weight can be attached to his judgment on the matter.

The age and authorship of this work are much disputed. It is once quoted by Origen, who flourished about A.D. 230. The most probable opinion is that of Cave and Lardner, who suppose it to have been written by a Jewish convert to Christianity about the end of the 2nd century after Christ.

It appears to have been the writer's object to foist his work into the Canon, since, though he makes frequent quotations from the books of the Old Testament, he never mentions any of them by name. The only book which he quotes by name is 'the book of Enoch the Righteous.'

These testaments have been frequently published in Latin. They were first printed in Greek by Grabe in his 'Spicileg. Patr.,' and afterwards by Fabricius in his 'Cod. Pseudepigraph.,' and Whiston published an English translation of them in his 'Authentic Records.'

(Lardner's *Credibility*, part ii., c. 29, § 3, and the authorities there quoted.)

TESTE OF A WRIT. [Writ.]

TESTIMONY. [Evidence.]

TESTIMONY, PERPETUATION OF. [Perpetuation of Testimony.]

TESTONE or TESTOON. [Money.]

TESTS, CHEMICAL, or Chemical Re-agents, are those substances which are employed to detect the presence of other bodies, by admixture with which they are known to produce certain changes in appearance and properties: thus, for example, as the blue colour of litmus is turned red by acids, it is considered as and used for a test to determine their presence when uncombined or in excess: so also litmus which has been reddened by an acid has its blue colour restored by the action of an alkali: reddened litmus is therefore used as a test of the presence of free or uncombined alkalies.

We give these examples from thousands which might have been selected, merely to explain the meaning of the term chemical test, observing that change of colour is one only of the many alterations adduced in proof of chemical action: thus the solubility of certain substances in some re-agents and not in others, constitutes another criterion or test of the nature of bodies.

We cannot enter particularly into this subject, for its extent is equalled only by its importance; and it is the less requisite that we should do so, since, in describing the various metals, &c., the tests of their presence are usually given with the properties of their salts. See also Chemical Analysis.

TETANUS (*τέτανος*, derived from *τείνω*, *to stretch*) is both a generic and a specific term: generically, it may be defined to be a more or less violent and rigid spasm of many or all of the muscles of voluntary motion; the name is also particularly applied (as will be seen hereafter) to one of the species of this affection. Both the disease and also its name are as old as the time of Hippocrates; and, as it is proved by experience to be much more frequent in warm climates, the ancient physicians probably had peculiar advantages in observing it, and accordingly seem to have paid particular attention to it.

"Tetanic spasms," says Aretæus ('De Caus. et Sign. Morb. Acut.,' lib. i., cap. 6, p. 6, ed. Kühn), "are attended with severe pain, and prove rapidly fatal, and by no means readily admit of relief; they make their attack on the muscles and tendons of the jaws and neck, but impart the disease to every other spot, for all parts become sympathetically affected with those which were primarily assailed. There are three forms of the convulsions: the straight, the backward, and the forward. The straight one is true *Tetanus*, when the patient is stretched straight and inflexible; the backward or forward varieties have their name from the direction and locality of the tension; hence the deflexion of the patient backwards is termed *opisthotonos* (*ὀπισθότονος*), from the nerves being affected in this direction; while, if the bending be forward, by the nerves in front, it is termed *emprosthotonos* (*ἐμπροσθότονος*), for *tonos* (*τόνος*) is a term which signifies both *a nerve* and *tension*."

The three forms of the disease mentioned by Aretæus are described by most of the ancient writers: the species called *trismus*, or *locked-jaw* (which is the name applied to it when the spasms are confined to the muscles of the jaw or throat), forms a fourth in modern authors; and to these has been added a fifth, under the name *pleurosthotonos* (*πλευροσθότονος*), which signifies that the body is drawn to one side. These different terms applied to tetanic affections do not imply so many particular diseases, but only the seat and various degrees of one and the same complaint. Trismus is invariably a part of each of the other varieties. This subdivision of the disease is of little or no practical importance; but a much more essential division is into *acute* or *chronic*, according to its greater or less intensity. The former kind is exceedingly dangerous and usually fatal; while the latter, on account of the more gradual progress of the symptoms, affords more opportunity of being successfully treated. (Larrey, in 'Mém. de Chirurgie Militaire' tome i.) Tetanus is also divided into *traumatic*, or that arising from a wound, which is also occasionally termed *symptomatic*; and into *idiopathic*, or that which proceeds from other causes.

Traumatic tetanus sometimes comes on in a surprisingly sudden manner, and quickly attains its most violent degree. The most rapidly fatal case that has ever been recorded is one that we have on the authority of the late Professor Robison of Edinburgh. It occurred in a negro, who scratched his thumb with a broken china plate, and died of tetanus a quarter of an hour after this slight injury. Most commonly, however, the approaches of the disorder are more gradual, and it slowly advances to its worst stage. In this sort of case the commencement of the disorder is announced by a sensation of stiffness about the neck, a symptom which, increasing by degrees, renders the motion of the head difficult and painful. In proportion as the rigidity of the neck becomes greater, the patient experiences in the throat a sense of dryness and soreness, and about the root of the tongue an uneasiness, soon changing into a difficulty of mastication and swallowing, which after a time become totally impossible. The attempt at deglutition is attended with convulsive efforts, especially when an endeavour is made to swallow liquids; and so great is the distress which accompanies these convulsions, that the patient becomes very reluctant to renew the trials, and occasionally refuses all nourishment; sometimes it even inspires him with a dread of the sight of water, and a great resemblance to hydrophobia is produced.

With respect to the causes of tetanus, "it must ever be regarded," says Dr. Gregory ('Theory and Practice of Med.'), "as a very singular fact in pathology, that an affection of so peculiar a character as this should have its source in causes apparently so dissimilar; that the puncture of a nerve, the laceration of a tendon, or an extensive burn, should bring on the same *kind* of nervous affection as that which is the occasional consequence of *cold*." Every description of wound, no matter how inflicted, or in what part, or in what stage, may be the occasion of tetanic symptoms which form the species denominated *traumatic*. Cases are on record wherein the patient was attacked with the disease in consequence of a bite on the finger from a tame sparrow; in which it supervened on the mere stroke of a whip-lash under the eyes, though the skin was not broken; in which it was occasioned by a small fish-bone sticking in the pharynx; by a slight solution of continuity in the external ear from a musket-shot; by the application of a seton to the thorax; by the stroke of a cane across the back of the neck; by a blow on the hand from the same instrument; by the extraction of a tooth, &c. In short, according to Sir James M'Grigor, "it occurs in every description and in every stage of wounds, from the slightest to the most formidable, from the healthy and the sloughing, from the incised and the lacerated, from the most simple and the most complicated."

Next in frequency to wounds as an exciting cause of tetanus is exposure to cold and damp; indeed there are but very few cases of true idiopathic tetanus which are referrible to any other. The irritation of worms and other disordered states of the alimentary canal have been considered by some authors as the cause of tetanic affections. To generate this form of disease, however, it would appear that a certain *predisposition* is also requisite, and it is doubtless the same with that which operates as an *accessory cause* of the traumatic tetanus. The predisposition to tetanic affections is given, in the first place, by warm climates and warm seasons. Within the tropics therefore it prevails to an extent unheard of in colder latitudes. Secondly, tetanus is chiefly observed to prevail when the atmosphere is much loaded with moisture, and particularly where this has suddenly succeeded to a long course of dry and sultry weather. Even in this country exposure to the cold and damp air of the night has occasionally been followed by an attack of tetanus. In tropical climates children are particularly subject to this complaint, and with a few peculiarities which, though producing no specific difference, have been thought sufficient to constitute a variety known by the name of *trismus nascentium*. The disease in this case is vulgarly known by the absurd name of *falling of the jaw*. It occurs chiefly between the ninth and fourteenth day after birth, and seldom after the latter period. Without any febrile accession, and often without any perceptible cause whatever, the infant sinks into an unnatural weariness and drowsiness, attended with frequent yawnings, and with a slight difficulty of moving the lower jaw. This last symptom takes place in some instances sooner, in others later, and soon increases in intensity. Even while the infant is yet able to open its mouth, there is occasionally an inability to suck or swallow. By degrees the lower jaw becomes rigid, and totally resists the introduction of food. There is no painful sensation, but the skin assumes a yellow hue, the eyes appear dull, the spasms often extend over the body, and in two or three days the disease proves mortal.

The prognosis of this disease is mainly to be determined by the nature of the exciting cause, and by the type of the seizure. Tetanus of the idiopathic kind has certainly been cured in a larger proportion of cases than that which follows external injury. The type of the disease as acute or chronic is a no less important guide as to the probable termination. It may be said that recovery in a case of acute tetanus is almost, if not altogether, hopeless: the chronic form, however, is of a much milder character. The usual termination of the disease may be stated to occur on the third or fourth day; and if the patient survives that time, there are good hopes of his recovery; it is rarely protracted beyond the eighth day. Mr. Cooper, however, mentions ('Surg. Dict.') that he had a patient (who had been wounded, and suffered amputation of the thigh) who lingered five weeks with chronic tetanus before he died.

The dissection of patients who have died of tetanus has thrown little or no light upon the real nature of the complaint, as is indeed the case in almost all spasmodic or neuralgic disorders. Sometimes slight effusions are found within the cranium, but in general no morbid appearance whatever can be detected within the head. There is always more or less of an inflammatory appearance in the œsophagus, and in the villous coat of the stomach about the cardia. These appearances, however, are common to a great number of diseases, and are uniformly met with in every case of rapid or violent death. Besides the redness and increased vascularity of these parts, Baron Larrey found the pharynx and œsophagus much contracted, and covered with a viscid reddish mucus. He also found numerous lumbrici in the bowels of several of the patients who died; but this, as Mr. Cooper remarks, could only be an accidental complication, and not a cause. In several cases Dr. M'Arthur found the intestines much inflamed; and in two of them a yellow waxy fluid, of a peculiar offensive smell, covered their internal surface; but whether the inflammation was primary, or only a consequence of the pressure of the abdominal muscles, which contract so violently in this disease, he is unable to decide. ('Med. Chir. Trans.,' vol. vii., p. 475.)

The treatment of tetanus is confessedly a subject of infinite difficulty, as the disease frequently baffles every mode of practice, and, in certain instances, gets well under the employment of the very same remedies which decidedly fail in other similar cases. Upon the whole it will probably be universally admitted that no effectual remedy for tetanus has yet been discovered, as every plan has occasionally succeeded, and every plan has still more frequently failed. An excellent abstract of the opinions of the ancients on this point is given by Mr. Adams in his Notes to Paulus Ægineta.

The general principle of cure, as Dr. Good remarks, is far more easily explained than acted upon: it is that of taking off the local irritation, wherever such exists, and of tranquillising the nervous erethism of the entire system. The former of these two objects is of great importance in the locked-jaw, or trismus, of infants; for, by removing the viscid and acrimonious meconium, or whatever other irritant is lodged in the stomach or bowels, we can sometimes effect a speedy cure without any other medicine. Castor oil is by far the best aperient on this occasion, and it may be given both by the mouth and by injections. If this, however, do not succeed, we should have recourse to powerful anodynes: of these the best is opium, which should be administered in doses of from three to five drops of the tincture, according to the age of the patient. Opium has also been more extensively resorted to in the cases of adults than almost any other remedy; and Dr. Good, Dr. Gregory, and others profess that it is that on which they place their chief, if not their only reliance. To give it a fair chance of success, we must begin its use from the earliest appearance of tetanic symptoms. It must be given in very large doses; and these doses must be repeated at such short intervals as to keep the system constantly under the influence of the remedy. It is astonishing to observe how the human body, when labouring under a tetanic disease, will resist the operation of this and other remedies, which, in its healthy state, would have been more than sufficient to overpower and destroy it. It is advisable to begin with fifty drops of laudanum, and to repeat this at intervals of two or three hours, or even oftener if the urgency of the symptoms require it, until some effect has been produced on the spasms. In the early stage of the disease we are to bear in mind the approaching closure of the jaw and difficulty of deglutition; and our remedies are accordingly to be pushed before such serious obstacles to their administration arise. When they have occurred, and are found to be insuperable, opiate enemata and frictions may be tried; but we must not anticipate much benefit from such feeble means. Such are Dr. Gregory's remarks; but Dr. Symonds considers that the employment of opium is recommended chiefly by systematic writers, and for theoretical, rather than for practical reasons; while most of those who give the results of their own experience express the greatest dissatisfaction with the remedy.

Probably a much more efficient class of remedies than the preceding is that of purgatives; both on account of the obstinate costiveness which attends the disease, and also because we have in daily practice such convincing proofs of their strong revulsive influence on diseases of the cerebro-spinal centre. The testimony of the army physicians, as we learn from the report of Sir James M'Grigor, is highly in favour of a rigid perseverance in the use of purgatives, given in adequate doses to produce daily a full effect. Dr. Forbes states that a solution of sulphate of magnesia in infusion of senna was found to answer better than any other purgative; and it was daily given in a sufficient quantity to produce a copious evacuation, which was always dark-coloured and highly offensive; and to this practice he chiefly attributes in one severe case the removal of the disease. ('Med. Chir. Trans.,' vol. vi., p. 452, quoted by Mr. Cooper.) Dr. Good condemns drastic purgatives, forgetting apparently that mild ones have no effect. Strong cathartics have indeed frequently proved of great service, and none has higher repute than croton oil.

The employment of the warm bath has been recommended by numerous writers, but it would be difficult to trace in their accounts any facts which decidedly show that its adoption was ever followed by unequivocal benefit. Cold bathing has also been advised, but it has generally been found to be worse than useless; and there are several cases upon record of almost instant death having followed its employment.

The practice of bleeding is another that has been tried, but most frequently without effect. In some few cases amputation of the limb, from the injury of which the tetanus has arisen, has been successful; but as this extreme measure is also very uncertain, it is not likely to be ever extensively adopted.

Numerous other remedies have been tried, with no, or very imperfect, success; for instance, acupuncture, strychnia, mercury, caustics, blisters, tobacco, oil of turpentine, ether, camphor, musk, bark, wine, sesqui-oxide of iron, &c., &c. However, it must, after all these have been tried, be confessed that tetanus is one of the most formidable and unmanageable of disorders, and that the recovery in the acute form still continues to be almost hopeless.

TETRACHORD, the Greek name for any part of the scale consisting of four notes, the highest of which is a perfect fourth to the lowest. Thus in the common diatonic SCALE (we assume a knowledge of this article throughout) we have the following tetrachords:—

CDEF, DEFG, EFGA, GABC, ABCD, BCDE.

We despair of giving anything like a satisfactory account of the Greek music; not that we think the difficulty lies in the Greek writers, but in the manner in which they have been treated. It was an assumption that the nation which produced models such as the moderns could not surpass in architecture, sculpture, and perhaps in painting, was to be considered as necessarily possessed of a system of music approaching to perfection. Their writers on the subject were to be taken as having an agreement with each other, which was to be detected and established, any apparent discrepancy, however evident, notwithstanding. The numerical relations which were the objects of inquiry in the settlement of the parts of the scale gave the subject the air of an exact science; and explanations which required the assistance of the scholar, the mathematician, and the musician, were undertaken by persons who were deficient in one character, if not in two. The consequence has been such a mass of confusion as the world never saw in any other subject; writers whose undertakings required them to say something, copying absolute contradictions from different other writers; others glad to adopt anything intelligible, whether true or not; others again, unable or unwilling to state the simplest facts of their own premises, so that their readers are not even made aware which of the most remarkable opposite opinions they mean to adopt.

We intend in the present article, without looking into any modern writer, to draw from Ptolemy and Euclid, writers who are known to be trustworthy on other subjects, all concerning the tetrachord that we can find to bear the character of certainty and precision, and to be likely to aid an unbiassed reader in approaching, should it please him so to do, the mass of different accounts which have been given.

All parties seem agreed that the Greek scale, which at first consisted of only two or three leading consonances, was gradually enlarged until it comprehended two octaves, or fifteen notes. It is generally stated that this scale, when it was what we now call diatonic (a word which means the same with us as with the Greeks), was minor in its character, so that in fact it would be represented by

$$ABCDEFGA^1B^1C^1D^1E^1F^1G^1A^1.$$

It is also known that the Greeks were early in possession of the mode of dividing a string so as to produce their several notes; and that, by the time of Ptolemy at least, they took the rapidity of the vibrations (on which they knew the pitch to depend) to be inversely as the lengths of the strings.

Their scales were numerous: three were considered classical, if we may use the word, and were called enharmónic, chromatic, and diatonic; the two first words not having the same meaning as with us. The remaining scales had names of locality attached to them, Lydian, Dorian, &c. The distinction between these lay in the different modes of dividing the octave, as seems to be now generally agreed, though there have been those who have thought that these terms, Lydian, &c., were the names, not of scales, but of single notes.

Of enharmonic, chromatic, and diatonic scales, Ptolemy lays down fifteen from his predecessors, and eight from himself. In each of them is an octave, and all of them agree in two particulars: first, each has the fourth and fifth of the fundamental note perfect; secondly, each has the tetrachord made by the fundamental note and its fourth divided in precisely the same manner as that of the fifth and the octave. That is, if we call the notes of this octave—

$$CPQFGRSC^1;$$

then CF is a fourth, and CG a fifth, always; and the interval CP, PQ, QF are severally equal to the intervals GR, RS, SC^1. Thus it appears that the fourth was to the Greeks what the octave is to us, the unit, as it were, of the scale, in the subdivision of which consisted the differences of their systems. We now give a tetrachord from each of these twenty-three scales, assigning the intervals first by the ratios of the vibrations, next by the number of mean semitones they contain, as in the article SCALE. We prefix the Latin rendering of Ptolemy's appellatives from Wallis.

And first as to enharmonic scales, which are mentioned first, and seem to have been ancient, and regarded with high approbation.

	Ratio of Numbers of Vibrations in each Interval.			Mean Semitones in each Interval.		
	CP	PQ	QF	CP	PQ	QF
Archytas	5 : 4	36 : 35	28 : 27	3·86	·49	·63
Aristoxenus Eratosthenes	19 : 15	39 : 38	40 : 39	4·10	·44	·44
Didymus	5 : 4	31 : 30	32 : 31	3·86	·57	·55
Ptolemy	5 : 4	24 : 23	46 : 45	3·86	·74	·38

It seems then that the enharmonic system would allow only of the following notes in an octave—

$$CEPFGBQC^1;$$

where P means a note about half way between E and F, and Q one half way between B and C^1. An odd scale truly for a modern musician to look at; but, it may be, not incapable of pleasing effects to ears not accustomed to music in parts.

The chromatic scales come next in order, as follows:—

	Ratio of Numbers of Vibrations in each Interval.			Mean Semitones in each Interval.		
	CP	PQ	QF	CP	PQ	QF
Archytas	32 : 27	243 : 224	28 : 27	2·94	1·41	·63
Aristoxenus, mollis Chromatica	56 : 45	29 : 28	30 : 29	3·79	·61	·58
Do., Sesquialterius Chromatica	37 : 30	77 : 74	80 : 77	3·63	·69	·66
Do., tonici Chromatica Eratosthenes	6 : 5	19 : 18	20 : 19	3·16	·94	·88
Didymus	6 : 5	25 : 24	16 : 15	3·16	·71	1·12
Ptolemy, mollis Chromatica	6 : 5	15 : 14	28 : 27	3·16	1·19	·63
Ptolemy, intensi Chromatica	7 : 6	12 : 11	22 : 21	2·67	1·51	·80

To make something as like as we can to these scales, we should write down in modern music

C E♭ E♯ F G B♭ B♯ C^1

The diatonic scales, Ptolemy allows, are more agreeable to the ear, and his specimens are as follows: we shall now write the scale with the usual letters throughout.

	Ratio of Numbers of Vibrations in each Interval.			Mean Semitones in each Interval.		
	CD	DE	EF	CD	DE	EF
Archytas	9 : 8	8 : 7	28 : 27	2·04	2·31	·63
Aristoxenus, mollis Diatonica	7 : 6	38 : 35	20 : 19	2·67	1·43	·88
Do., intensi Diatonica	17 : 15	19 : 17	20 : 19	2·17	1·93	·88
Eratosthenes[*]	9 : 8	9 : 8	256 : 243	2·04	2·04	·90
Didymus	9 : 8	10 : 9	16 : 15	2·04	1·82	1·12
Ptolemy, mollis Diatonica	8 : 7	10 : 9	21 : 20	2·31	1·82	·85
Do., tonici Diatonica	9 : 8	8 : 7	28 : 27	2·04	2·31	·63
Do., intensi Diatonica	10 : 9	9 : 8	16 : 15	1·82	2·04	1·12
Do., æquabilis Diatonica	10 : 9	11 : 10	12 : 11	1·82	1·65	1·51

These scales have all so far the diatonic character that they divide the tetrachord into two larger intervals followed by a smaller one: the scale of Didymus would have been exactly the modern untempered diatonic scale, if he had inverted the order of the two larger intervals in his second tetrachord. As to the other modes, the Dorians, &c., there is much confusion in Ptolemy respecting them, arising from the corruptness of the text, which Wallis has endeavoured to remedy. According to him, there are divisions of the octave, somewhat more fantastic than those which precede. In more recent times the idea has been started of their being simply different keys, or rather answering to different variations of the diatonic scale, by using intermediate semitones instead of some of the notes: it would be difficult, we think, to produce authority enough for this conjecture.

If it were true, as supposed, that the two octaves of the Greek scale, beginning, say with A, were minor, it would follow that Ptolemy, in his diatonic scales, exhibited the octave from C to C^1, as we have supposed. Accordingly, the principal mode of exhibiting the formation of the octave from two tetrachords and a tone would be the one we have taken, namely,

(C D E F) (G A B C^1)

But it is frequently supposed that it was the following:—

C {D E F (G} A B C)

or the following—

A {B C D (E} F G A)

On this point we shall only say that there never was, we believe, so strong a union of the three characters of scholar, mathematician, and musician, as was seen in Dr. Smith, the author of the Harmonics. He had studied the Greek scale attentively, and to him the first of these methods was a matter of course. "The Greek musicians" ('Harmonics,' 1749, p. 45), "after dividing an octave into two-fourths, with the diazeuctic or major tone *in the middle between them*, and admitting many primes to the composition of musical ratios, subdivided the fourth into three intervals of various magnitudes placed in various orders, by which they distinguish their kinds of tetrachords."

We do not, we confess, though admitting that it is exceedingly hard, and probably impossible, to reconcile the Greek writers with themselves and each other, find that sort of difficulty which Dr. Burney owned to, when he said that he neither understood those writers himself, nor had met with any one who did. He was a musician, and was looking out for an intelligible mode of arriving at and distributing the most agreeable concords, with a strong predetermination to arrive at musical truth or nothing. But the Greek writers were arithmeticians, with as strong a determination to find natural foundations in integer numbers: they did not ask how to find sounds which would best suit the ear, but how to discover triplets of fractions which multiplied together should produce four-thirds of a unit. Pleased with the simplicity of the ratios which give the fourth, fifth, and octave, their efforts at musical improvement were confined to the attempt at discovering magic numbers to fill up the intervals. It was not until one of these philosophers had laboured at his abacus, and tasked his metaphysics to find *à priori* confirmation of some question in arithmetic, that he strung his monochord and tried how his scale sounded: it would have been hard indeed if his ear had refused to sympathise with his brain. In all probability the musicians, whose object was simply to please, laughed at the arithmeticians, as Tycho Brahé did at Kepler, when the latter had discovered reason for the distances of the planets in the properties of solid bodies: they had motive enough, and, beyond all question, reason more than enough.

TETRAGON (properly a four-angled figure), a term usually applied to the square only, when used, which it seldom is. [REGULAR FIGURES.]

TETRAHEDRON (a solid of four faces), a term usually applied to the regular tetrahedron. [REGULAR FIGURES.]

TETRAMETHYLAMMONIUM. [ORGANIC BASES, *Methylamine.*]

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[*] This is also Ptolemy's Ditonici Diatonica.

TETRAMYLAMMONIUM. [Organic Bases.]

TETRARCH (τετράρχης), from two Greek words, signifying *four* and *to govern*, a title used by the Greeks at a very early period to describe the ruler of each part of a country which was divided into four parts, either on account of its occupation by different tribes, or merely as a political division. Each of such four parts was called a tetrarchy (τετραρχία or τετραδαρχία). In process of time the title came to be applied to the rulers of different divisions of the same country, or to the chiefs of different tribes inhabiting the same country, without any reference to the number four. In this sense it was equivalent to the titles *ethnarch* and *phylarch*. Under the Roman government, in the later ages of the republic and under the emperors, there were several such petty princes, independent of each other, but tributary to Rome. These *tetrarchs*, *ethnarchs*, or *phylarchs*, were either the legitimate governors of their subjects, or persons who had received the title and government from Rome as a mark of honour. They ranked below those other subject princes who were permitted to retain the title of king.

The principal examples of tetrarchies are those of Thessaly, which was anciently so divided, and the division was again made by Philip, the father of Alexander the Great: of Galatia, which was peopled by three Gallic tribes, each of which was divided into four tetrarchies: of Syria, many of the petty princes of which bore the title of tetrarchs, especially certain princes of the family of Herod the Great. Concerning the tetrarchs of Syria, see Niebuhr's 'History of Rome,' ii., pp. 134-5.

TETRATHIONIC ACID. [Sulphur.]

TETRETHYLAMMONIUM. [Organic Bases.]

TETRYL. [Butyl.]

TETRYLAMINE. Synonymous with *butylamine*. [Butyl.]

TETRYLENE. *Butylene*. [Butyl.]

TETRYLHYDROSULPHURIC ACID. Synonymous with hydrosulphate of butyl. [Butyl.]

TETRYLSULPHURIC ACID. *Sulphobutylic Acid*. [Butyl.]

TEUTONIC NATIONS is the general name under which are comprised the different nations of the Teutonic race. These are divided into three branches. The first branch contains the High Germans, to whom belong the Teutonic inhabitants of Upper and Middle Germany, those of Switzerland, and the greater part of the Germans of Hungary; it is subdivided into the Suabian and the Franconian minor branches. The second is the Saxon branch, which is divided into three minor branches: the first of which contains the Frisians; the second, the Old Saxons or Low Germans, with the Dutch, the Flemings, and the Saxons of Transylvania; and the third, the English, the Scotch, and the greater part of the inhabitants of the United States of North America. The third branch is the Scandinavian, to which belong the Icelanders, the Norwegians, the Danes, and the Swedes. It has been estimated, but on no very exact data, that nearly 100,000,000 individuals belong to the Teutonic race. The Germans amount to above 42,000,000, 33,000,000 of which live in Germany, the remaining 9,000,000 form a greater or less part of the population of East Prussia, of Switzerland, of Hungary, of Transylvania, of France, (in Alsace and north-east Lorraine), of Russia (in the Baltic provinces, in the kingdom of Poland, in the Crimea, in Bessarabia, and in the German colonies in the environs of Saratov on the Volga), of the duchy of Sleswig, and of the United States of North America, especially Pennsylvania. The English amount to about 33,000,000, there being about 18,000,000 of English and Scotch in Great Britain and Ireland, nearly 3,000,000 in the English colonies, and 11,000,000 or 12,000,000 of Anglo-Americans in the United States. The number of the Frisians is about 130,000, in the province of West Friesland in Holland, in the islands in the German Ocean along the Dutch and the German shore, in the Saterland (near Oldenburg), and in the islands along the west coast of the duchy of Sleswig. There are about 3,000,000 of Dutchmen in Holland and in her colonies and the Cape of Good Hope; and there are about 2,500,000 Flemings in the north part of Belgium, in the south part of Holland, and in the north-east part of France. The number of individuals belonging to the Scandinavian branch amounts to at least 6,000,000, among whom there are—50,000 Icelanders; 1,500,000 Danes in Denmark, in her colonies, and in the north part of the duchy of Sleswig; 1,250,000 Norwegians; and about 3,200,000 Swedes in Sweden and in the present Russian province of Finland, especially along the coast of the Gulf of Bothnia, in the districts of Abo and Nyland, and on the Aland Islands, which are entirely inhabited by Swedes.

Light hair and blue eyes in the northern countries, and brown hair and brown or blue eyes in some of the southern countries, are characteristics of the Teutonic race. Their stature is generally tall, although in those provinces where the Germans are mixed with Wends, Suabians, and Bohemians, many of the people have the broad shoulders and the short square form of the north-western Slavonians. The straight black hair of some Slavonian tribes also sometimes appears. The mixture of Germans with the south-west Slavonians, such as Wends and Croatians, whose stature exceeds that of the Wends and Bohemians, is more difficult to be distinguished, the black straight hair and a darker complexion being almost the only indication of such a mixture. The mixture of Germans with Celts in Belgium and in the adjoining part of France has formed a tall race which differs from their Teutonic neighbours only in the dark colour of their hair and their black eyes. (Platé, 'Scenen aus dem Volksleben in Belgien.')

It is very difficult to distinguish the descendants of English and Irish parents as belonging either to the Teutonic or the Celtic race, though it appears that wherever aquiline noses are seen among the lower classes they are a proof of Celtic origin, the true Teutonic nose not being aquiline, but either straight or curved only in its upper part. In general, also, the Teutonic forehead is broader between the temples than the Celtic. (Clement, 'Die Nordgermanische Welt;' Herder, 'Ideen zur Philosophie der Geschichte,' vol. i.)

The moral and intellectual difference between the Teutonic nations is less remarkable than that which exists between other European nations of the same race with one another. Capable of strong and violent passions, they do not easily lose their self-control, the intellectual functions being more developed than in most other races. Southern nations, confounding liveliness of feeling with intensity, and nervous excitability with moral sensibility, have been deceived by the cool character of the Teutonic nations, and have accused them of indifference. But the most superficial examination will show their sensibility—a fact which is proved by their poetry. The Teutonic nations are less excitable than the Celtic, the Slavonian, and other races, but capable of deeper thought. Southern nations have accomplished great things by sudden efforts; the Teutonic nations have reserved their enterprise for vast plans, which it requires centuries to carry into effect. Thus they destroyed the Roman empire after a struggle of three centuries, and they formed new kingdoms in Europe upon new social principles, which have maintained their vigour to the present day. The Normans became powerful wherever the sea permitted them to effect a landing. The Germans, diminished in number after they had sent their swarms to Western Europe, turned back towards the east part of their country, then occupied by Slavonian nations, which they conquered, and Germanised upon a plan of colonisation which enabled them to civilise the east of Europe. And lastly, the English colonies have spread over the world: their dominion in the east and in the west is the result of plans which imply more boldness of conception, more prudence in execution, and more reflection, than the conquests of Alexander the Great and the ephemeral power of Napoleon.

The same character of deep and patient reflection exercised on great objects appears in German philosophy and in the inventions of the Teutonic nations. The watch, the gun, and the art of printing are Teutonic inventions. They have subjugated the power of steam; and the first model of the modern sea-vessel was constructed at the mouth of the Eider by the hands of an old Saxon or Frisian ship-builder. (Clement, *ibid.*)

The name of the Teutones was made known to the ancients by Pytheas of Massilia (Marseille), who, in the age of Alexander the Great, about 320 B.C., discovered a nation of that name in the Chersonesus Cimbrica, and on the adjacent islands, or in the present countries of Holstein, Sleswig, Denmark, and perhaps also in the southern extremity of Sweden. It seems that they had long been settled there, for they lived in houses, and were acquainted with agriculture and commerce. Other traces of the name appear later. Among the Celtic tribes which invaded Greece and besieged Delphi under the second Brennus (278 B.C.), there was a people called Teutobodiaci, who afterwards passed the Hellespont and settled with the Celts in Galatia, in Asia Minor. About 160 years later, the Romans were attacked by the Cimbri and Teutones, who came from the same country, where they had been seen by Pytheas. The Teutonic origin of the Cimbri has been disputed: some historians consider them identical with the Celtic Cymri, but this error has been long since refuted, although it has been reproduced in our days by Thierry, in his 'Histoire des Gaulois.' It is said, and it is not improbable, that inundations of the sea compelled the Teutones and their neighbours the Cimbri to leave their country and to seek other abodes. The choice was soon made. The wealth of Rome and the arts of Greece were not unknown to them. From the most remote times adventurous merchants, starting from the shores of the Black Sea, followed the course of the Dnieper towards its sources, and reaching the Düna and the Niemen, descended these rivers to their mouths in the Baltic, where they exchanged the commodities of the south for amber, the electrum of the ancients. The same trade, as it seems, was carried on by the merchants of Massilia along the Rhône and the Rhine, and therefore Schlözer, in his 'Nordische Geschichte,' says that but for the amber Germany would have remained unknown to the ancients for five centuries more. Their acquaintance with Rome and Massilia was perhaps the principal cause which led the Cimbri and the Teutones to the south of France and to Italy (B.C. 113–99). Their destruction by Marius has been related. [Marius, in Biog. Div.; Cimbri.]

When the Romans first heard the name of the Teutones, they thought that they were a single tribe. They did not know that it was also the general and ethnographic name of all those nations to which they afterwards gave the vague designation of Germans.

Origin of the name Teutones.—The root of the word Teuton is *thu* or *do*, which originally represented the idea of "activity," of "living, procreating, nourishing," and also of "taming, educating, and ruling." From this root are formed the following words, some of which are still used in the popular dialects:—*Tuit*, god, creator, ruler, father, nourisher (*Thor*, *Tuisco*); *thut* or *thiud*, earth; *tott döte*, *dote*, godfather; *toda*, nurse; *thiod*, father of the people, lord, ruler, king, in Gothic *thiudans*, in old Bavarian *theodo*; *diet*, people, in old Swedish, *thiaut* and *thyd*; *thiudinassus*, in Gothic, kingdom. (Fulda, 'Wurzel-Wörterbuch.') The idea of ruling, expressed by the root *Teut*, explains why this word occurs so frequently in the names of the ancient Teutonic kings, dukes, or chiefs, such as Teutoboch, Theudorix, Diorix, Theodorix, Theodoric, Theodomir, Theodimir, Teutagon, &c. It is likewise contained in the general name of all the Teutonic nations, and in those of various tribes, as the Teutones, the Teutonoarii, Thaifali, and the Dithmarses or Dietmarses. *Teuton* is identical with *Deutsche* or *Teutsche* (in Low German, *Dütsch*; in Dutch, *Duitsch*; in Danish, *Tysk*; in English, *Dutch*), which from the remotest time has been and is still the general name of that part of the Teutonic nations which we now call Germans, who considered the god or hero Tuisco as their common ancestor. There are no direct proofs of the word Teuton having had this extensive meaning in the earliest German history, but this is perhaps the result of the political state of the Teutonic nations, which were originally divided into numerous tribes, each of which became separately known to the Romans.

Origin of the Teutonic Nations.—The Teutonic race is originally from Asia. The Teutones immigrated into Europe at different periods unknown to history, although it appears that the last of them entered Europe during the migration of nations in the 4th and 5th centuries. Some account of their Asiatic origin is given in their ancient national songs, principally in the Sagas of the Scandinavians. It is also said that Benedict Goesius (Goez), a Jesuit, found in 1603, in the mountains of the Hindu Kush, north-east of Cabul, a people with fair hair like the Dutch, and who are perhaps identical with that tribe of which Pliny speaks, and which was settled in the Montes Emodi. But all this is of little value, unless it is corroborated by other facts. Such facts have been furnished by the learned philologists of our age, especially by Friedrich von Schlegel, Adelung, Bopp, Grimm, and Hammer-Purgstall. A comparison of the Teutonic languages with the Persian, the Zend, and the Sanskrit, has shown the relationship which exists among these languages [LANGUAGE; SANSKRIT LANGUAGE and LITERATURE], and by means of these facts, the Mythes and Sagas become important for history.

When the Teutonic nations appeared in history, they were divided into many bodies or confederations of tribes, such as, at a later period, the Franks, the Suevi, the Saxons, the Marcomanni, and the Alemanni. Long before these names were known, there was a similar confederation of tribes which came from the north-north-east and conquered the countries on the left bank of the Rhine, then inhabited by Celtic nations, which fled to their brethren in Central Gaul. The epoch of this invasion is not known, but the event happened a long time before the age of Cæsar, who found those countries settled by a Teutonic population. Tribes of the Condrusi, the Eburones, the Caeraesi, and the Paemani, were united in a confederation, and had adopted the name of Germani, or "war-like men." This name was gradually used by the Romans to designate other nations which belonged to the Teutonic race (Tacitus, 'Germ.,' c. 2), and subsequently it was adopted by the English as a name for the "Deutsche," while this very name, changed into Dutch, now designates the inhabitants of Holland.

The Teutonic Nations after Cæsar.—When Cæsar reached the Rhine, Northern Germany, Holland, Belgium, and a part of the countries on the Middle Rhine were inhabited by Teutonic nations which belonged to the northern, now Saxon, branch. They had been settled in fixed habitations for several centuries, and they must be considered as the first of this race which settled in Germany. The southern part of this country was then inhabited by Celts and Rhaetians, except the tract between the Upper Rhine and the Upper Danube, which was conquered by the Suevi, who belonged to the Teutonic race. The word "Suevi," which comes from "schweifen," may be translated "wanderers," or people who rambled about for the purpose of settling in any convenient country. It was adopted by a great number of tribes, the majority of which belonged to the High Germans, and came from the countries on the Baltic between the Oder and the Niemen. Cæsar was obliged to fight with their leader Ariovistus (B.C. 58), who had invaded Gaul. Ariovistus was compelled to go back to Germany.

Tacitus divides the Germani into three great bodies: the Ingaevones, in the north; the Istaevones, in the west, from the mouths of the Rhine upwards to Basel; and the Hermiones, in Middle Germany and towards the north-east. This division seems to have an ethnographic and still more a political value. The position of the Ingaevones corresponds to that of the later Saxons, and both the names have one meaning, Saxon signifying a settled people, and In-gae-vones a people who live in a cultivated country divided into districts (In-gau-wohner or Inwohner). The Istaevones, or Western Germani (West-wohner), correspond to the later Franks, and the Hermiones to the Suevi, including the Alemanni. Further, the name of Hermiones is undoubtedly identical with Hermunduri, one of the greatest Suevian or High-German tribes, the name of which is generally supposed to be the same with Doringi or Thuringi, the present Thuringians.

From the time when Cæsar first met with the Suevi under Ariovistus, there was a deadly enmity between the Romans and the Germans. The Romans wished to make Germany into a province, and the Germans aimed at the possession of Gaul: on both sides there was the passion of conquest and the necessity of self-defence. Ambition pushed the Romans into Germany, and want of fertile lands, and perhaps some great revolution among the nations of Eastern Europe, led the Germans into Gaul and Italy. The Roman eagles were seen in the wilds of the Hercynian forest, but Arminius saved his nation from slavery in the forest of Teutoburg, in Detmold, where Varus was slain with three legions (A.D. 9). The campaign of Germanicus, who advanced as far as the Elbe, led to no results, though he gained a complete victory over the Germans on the field of Idistavisus near the Weser (A.D. 16); when he celebrated his triumph in Rome (A.D. 17), the Germans between the Rhine and the Weser were as free as before. These tribes made a confederation, and chose Arminius for their leader. A war arose between him and Maroboduus, king of the Marcomanni, who was defeated and obliged to implore the assistance of the Romans (A.D. 19). Being attacked by Catwald, or Catualdus, the chief of the Gothones, he lost his crown, and the confederation of the Marcomanni was broken. Arminius, the hero of Germany, fell by the hands of his jealous kinsmen, in his thirty-seventh year. (Tacitus, 'Annal.,' ii. 88.)

Notwithstanding the civil wars in Germany, the Romans gave up the idea of conquering the country, and Tiberius ordered a defensive system to be observed on the frontiers, which were formed by the Rhine from its mouths to the Moselle, and from the junction of this river with the Rhine they followed the Lahn as far as the present district of Wetterau. The frontier then took a southern direction, passed the Main at Obernburg, the Jagst at Jagsthausen, the Kocher at Hall, and joined the Danube near Pföring, from which town it ran along the Danube as far as Pannonia. The rivers were defended by castles, and the tracts between them by a strong rampart with towers, the Vallum Romanum of Hadrianus, a considerable part of which, the Pfahlgraben, is still visible. The Germans west and south of this barrier became Roman subjects, but those who lived east and north of it enjoyed their ancient liberty.

All the German tribes practised agriculture, but warfare being their favourite occupation, they abandoned their fields and their flocks to the care of bondsmen. The fine arts were not exercised among the Germans, but they were acquainted with the art of writing [RUNES], although only for religious purposes. (Rhabanus Maurus, in Goldast, 'Script. Rer. Alem.,' ii. 1; Hickesius, 'Thes. Ling. Septentr.') The groundwork of their social and political constitution was the union of a certain number of families into a community, "Marcha," "erdmarcha," now "Mark-Genossenschaft." Mr. Kemble, in his 'Saxons in England,' has shown the prevalence and the importance of the divisional mark in England. Several marchas formed a "gow," now "gau," a district which had its own administration. Twice a month, and sometimes every week, the members of a gow assembled and held the "gowding;" the gowdings were civil and criminal courts, and also meetings for legislation, and war and peace were decided on in them. Besides the gowdings there were "graven" or "greven" (graviones, comites), or delegates of the gowding, who were assisted in their judiciary functions by a certain number of freemen. The magistrates were chosen from the nobles (edelings or adelings), the "principes" of Tacitus, who had also the right of forming a kind of senate, where they deliberated on important affairs previously to their being brought before the gowding, and they despatched matters of little importance, which did not come before the gowding. The nobles had also the privilege of keeping a "dienst-gefolge," or a band of freemen who served them in their feuds and wars; and they had individually the right of protecting unfree people in the gowding, a right which also belonged to the community as a body, but not to individual freemen. The privileges of the nobles were probably connected with the religious institutions, of which we have no positive knowledge, although it appears that priests and nobles formed only one class, an opinion which is corroborated by the fact that wherever Christianity was introduced into Germany, it met with no opposition from the common people as soon as the nobles were converted. Some of the earlier Teutonic nations had hereditary kings, the "reges" of Tacitus, who however had a very limited authority. The greater part of them chose princes only as commanders of the army in time of war. The name of these commanders was "herzog," in low German "hertog," or "hartog," in Latin "dux."

Besides the freemen and the nobles, there were bondsmen, "lazzi," "lati," or "liti," now "leute;" in low German "lüde," or "lide;" who were either the primitive inhabitants of a conquered territory, or prisoners of war, or freemen who had lost or sold their liberty. Their condition was in no way like that of the Roman servi, who, legally speaking, were not considered as persons, but in most respects things. Domestic and personal services, and especially agriculture, were their exclusive occupations.

The military organisation of the Teutonic nations was founded on two principles. When a gow, or a confederation of several gows, determined on war, every freeman was obliged to take up arms for the defence of the commonwealth. But war was sometimes made for the private interest of some powerful noble, who carried it on with his "dienst-gefolge," which was a numerous body when the military renown of the chiefs, or the hope of easy conquests, promised rich rewards to the adventurous band.

We know little about the religion of the ancient Teutonic nations. They worshipped a supreme being under the name of Woden or Odin, but the true character of their religion was the worship of Nature in her different manifestations. Thor, Hertha, and Freya were personifications of the power of heaven, of earth, and of love and procreation. [Scandinavian Mythology.]

Such was the moral, social, and political state of the Teutonic nations when they began their wars with Rome. The Vallum Romanum prevented them from invading the Roman empire during the 1st and 2nd centuries. In the 3d century they often crossed it. In the 4th they conquered a considerable part of the countries on the Danube; and in the 5th they invaded and conquered all the European provinces of the Roman empire.

Alemanni. [Alemanni, in the Geog. Div., under which head the political history will be found.]—The *Lex Alemannorum* was revised in the time of Dagobert, king of the Franks, and again by Lantfried, the Frankish duke of Alemannia, in the beginning of the 8th century. There is no trace of the Roman law in it except in one single case (tit. 80). The Lex Alemannorum, as well as all the other earlier codes of the Teutonic nations, are contained in Ferdinand Walter's 'Corpus Juris Germanici.' Sichard published an edition of it in the 'Leges Ripuariorum, Bajuvariorum, et Alemannorum,' 1530, 8vo. Besides these collections, the Teutonic laws are in the collections of Herold, Lindenbrog, Eccard, Heineccius, Georgish, Canciani, and Baluzius.

Burgundians. [Burgundians, Kings of the, in Biog. Div.]—The Burgundians came from north-east Germany, and first assisted the Alemanni against the Romans; but they left Germany as early as the beginning of the 5th century, penetrated into Gaul, and formed the powerful kingdom of Burgundy on both sides of the Jura, which was incorporated with the kingdom of the Franks in 534. The collection of the Burgundian laws, Lex Burgundionum, 'Gundobada,' 'Gundobarda,' 'Loi Gombette,' was made towards the end of the 5th century, under king Gundobald, who died in 516, and was augmented (517) by king Siegmund, who died in 523. The legislation of Gundobald goes as far as title 42. The following titles, although they contain laws and regulations of Gundobald, were added by Siegmund, who completed the code by two "additamenta," containing his own laws. Charlemagne made a third additamentum, without altering the code itself. The Lex Burgundionum, which is written in much purer Latin than most of the other Teutonic codes, contains several of the rules of the Roman law concerning donations, and especially testaments (tit. 43 and 60). A separate edition was published at Lyon in 1611.

Franks. [France, in the Geog. Div., gives the political history of the Franks.]—In the very countries which the Romans traversed on their way to the woods where Varus was slain, the Usipetes, the Tencteri, the Sicambri, the Bructeri, the Ansibarii, the Marsi, the Tubantes, the Chamavi, and the Chatti—all tribes belonging to the northern, now Saxon branch (Ingaevones) of the Germani—formed a confederation and called themselves Franks, either because they were particularly "free and bold," or on account of their "barbed lances" (frameæ). The Franks were divided into Franci Salici, who lived in the Low Countries between the Zuider Zee, the Maas, and the Somme; and Franci Ripuarii, who were settled along the Rhine between Nymegen and Bonn. Each of them had their code. The *Lex Salica* was written in very barbarous Latin, under Clovis, between 484 and 496, and was never revised, although it contains some laws by the sons of Clovis, which begin with the 62nd (63rd) title. Except one rule in title 14, about the rape of free persons, and another concerning marriage within the prohibited degrees, this code contains no trace of the Roman law. It is very important for the history of the laws of the Teutonic nations. The ancient Lex Salica is often confounded with the present Salic Law, which regulates the right of succession in several sovereign and noble families in Europe. But this latter Salic law is only a single rule of the *Lex Salica,* and originally concerned the succession to the tax-free estates of free or noble Franks (*terra Salica*), which belonged to the male issue, to the exclusion of females. It is contained in title 62, 'De Alode,' l. 6: "De terra vero Salica nulla portio haereditatis mulieri veniat: sed ad virilem sexum tota terrae haereditas perveniat."

This law was not peculiar to the Franci Salici: it occurs in the greater part of the other ancient Teutonic laws. (Wiarda, 'Geschichte und Auslegung des Salischen Gesetzes;' Heineccius, 'Ant. Germ.', i., p. 265, 285; a separate edition of the Lex Salica was published by Pithou, Paris, 1602, 8vo.) The *Lex Ripuaria* was collected by Theodoric, the son of Clovis, between 511 and 534. It was several times revised, especially by Dagobert. It resembles the Lex Salica, and contains no traces of the Roman law.

Goths. [Goths, Gothi, Gothones, for the history.]—The Code of the Ostro-Goths, 'the Edictum Theodorici,' which was composed by order of Theodoric in 500, is a collection of Roman laws. This king wished to form one people of the Romans and the Goths ('Edictum,' § 30), and he therefore adopted the laws of the most civilised of his subjects. Leaving the Gothic laws exclusively to the memory of the people, he knew that they would soon fall into oblivion without being formally abolished. In some cases, however, he supplanted Gothic customs by Roman laws. The *Wehrgeld,* or *Wehre,* —that is, the fine for crimes,—was entirely abolished, and in place of it the punishment of death was introduced in many cases, an innovation which seemed very hard to the Goths, who, like all the other Teutonic nations, inflicted the punishment of death only for high treason and a few such crimes. Pithou published a separate edition of the 'Edictum Theodorici' (Paris, 1579). Rhon, 'Commentatio ad Edictum Theodorici, Reg. Ostrogoth.', Halae, 1816, 4to.

The *Visi-Goths* settled in the southern part of Gaul in 412, and invaded Spain in 414. This country was then in the hands of the Suevi, the Alani, and the Vandals, who became subject to the Goths, or were forced to emigrate. In 451 the Visi-Goths, together with the Franks, defeated Attila and his 700,000 Huns, Goths, Gepidae, and other vassals, in the plain of Châlons-sur-Marne. Their king, Alaric II., lost Gaul, except the eastern part of Languedoc and Provence, in the battle of Vouglé against Clovis, king of the Franks, in 507. The kingdom of the Visi-Goths lasted for three centuries, when it was overthrown by the Arabs in 712.

Among all the Teutonic nations the Visi-Goths were the first who had written laws. (Isidorus Hispalensis, 'Chron. ad annum Aer. Hisp. 504, A.D. 466.') A collection of them was made by their king Euric (466-484), which is written in Latin and has the title of 'Lex Visigothorum.' Its present form dates from king Egica, whose new code was translated into the Gothic language under King Receswind. It contains many traces of the Roman law, and is the only early Teutonic law which may be considered as a code in the modern signification of the word. The Lex Visigothorum must not be confounded with the Breviarium Alarici (Alaric II., in 506), or the Code for the Romans, who were subjects of the Visi-Goths, and continued to live under their own laws until they were abolished by the kings Chindaswind and Receswind, who declared the revised Lex Visigothorum obligatory on all the inhabitants of the kingdom of the Visi-Goths.

The Goths, the most civilised among the Teutonic nations, were the first who adopted the Christian religion. They had a literature from the time when Ulphilas translated the Bible. The Ostro-Goths soon disappeared among the Longobards, while the Visi-Goths preserved their language and nationality till the invasion of the Arabs; and another portion of them maintained their nationality until a very recent period.

These were the *Gothi-Tetraxitae,* who, after the emigration of their brethren to the western countries, retired to the eastern part of the Chersonesus Taurica, now the Crimea, and the opposite island of Taman. There they lived for eleven centuries under the successive dominion of Huns, Bulgarians, Greeks, Khazars, Tartars of Kiptshak, and Tartars of the Crimea, and, lastly, of Turks Osmanlis. Their part of the Crimea was called Gothia during the middle ages. Busbequius, who was the ambassador of the emperor Rudolph II. at Constantinople, towards the end of the 16th century, is the last writer who mentions them. It appears that they afterwards adopted the language, the customs, and the religion of the Tartars. Russian scholars have traced the Gothic language among the Tartars of the Crimea. ('Journal de St. Pétersbourg,' 1829.)

Another part of the Goths invaded Sweden, and founded the kingdom of Gothland (Gautland), which was afterwards divided into East Gothland and West Gothland (Eystra-Gautland and Vestra-Gautland). They mixed with the Scandinavians, and it became a general opinion that they were originally the same people. But a comparison of the Gothic of Ulphilas and the old Scandinavian language shows that this opinion is unfounded. (Olaus Verelius, 'Gothici et Rolfi Westrogothiae Regum Historia,' Upsalis, 1664; Antonius, 'Bibl. Hisp. Vet.', i.; Michael Geddes, 'Miscellaneous Tracts,' vol. ii. diss. 1; vol. iii., diss. 1; 'Manso, 'Geschichte des Ostgothischen Reichs in Italien;' Mascov, cited below, ii.)

Suevi.—From the country east of the Black Forest, between the Upper Danube and the Alps, the Suevi, by which name the Quadi and the Hermunduri were perhaps likewise meant, spread over Gaul and forced their way into Spain (406–409). Their king Hermanaric or Hermanrich became master of Portugal, Galicia, and the western parts of Asturias, and Leon: he resided at Bretonia, near the mouth of the Miño, now a small village named Bretaña. His successors were independent kings, but in 585 the Suevi became subjects of Leovigild, king of the Visi-Goths. Their laws have not been collected. They were at first Catholics, but king Remismund (461) professed Arianism; Theodemir (Ariamir) returned to the Catholic faith in 561.

Vandals.—This name, which was known to Tacitus, comprises various tribes of Teutonic and also of Slavonian origin, who lived in Eastern Prussia and Pomerania. The Slavonian tribes were subject to the Teutonic Vandals, who are often confounded with the Wends (Venedi), who afterwards occupied the country of the Vandals. The Vandals left their homes towards the end of the 4th century, and a part of them, after a sojourn in Pannonia, traversed Germany and Gaul, and founded the Vandal kingdom in Spain in 409. In 417 they subjugated the Alani, who had also settled in Spain. In 429 they were forced by the Visi-Goths to abandon this country, and they went over to Africa. Their king Genseric or Geiseric took Carthage (439), all Mauritania, and the islands of Sardinia, Corsica, the Baleares, and the western part of Sicily. On the 12th July, 455, they plundered Rome, and their name became proverbial as that of the most barbarous among the barbarians. Their kingdom lasted till 535, when it was destroyed by Belisarius, and became a part of the Byzantine empire. All the names of the Vandal kings are Teutonic, and resemble those of the Gothic kings, a fact which proves that however numerous the

Slavonians were among them, the Teutonic tribes were the ruling nation. Their name is visible in that of the province of Andalusia or Vandalusia. (Papencordt, 'Geschichte der Vandalen.)

Longobards. [LOMBARDO-VENETIAN KINGDOM, in GEOG. DIV., col. 578.]—The Longobards lived on the right bank of the Lower Elbe, and afterwards on the left side of this river, near Lüneburg and Brunswick: in language and person they resembled their neighbours the Saxons, a strong body of whom appeared with them in Italy. Before they invaded Italy they had lived in the present country of Upper Hungary; in Pannonia, and in Noricum (494–568). Their king Alboin subjugated the Gepidæ in Transylvania (563?), and in 568 he conquered the greater part of Italy. Their last national king, Desiderius, was deprived of his throne by Charlemagne (774), who assumed the title of king of the Longobards: but the Longobards neither lost their constitution nor their estates; the only change was in the reigning dynasty.

When the Longobards were subjugated by the Franks, they had possessed written laws for 130 years. The first collection was made by king Rotharis in 643. The laws of Grimoald were collected in 668, those of Luitprand between 713 and 724; those of Rachis in 746, and those of Aistulf in 754. They contain only a few heads of Roman law concerning prescription and succession. (Muratori, 'Script. Rer. Ital.,' tom. i.; and especially Biener, 'De Origine et Progressu Legum Jurumque Germanicorum,' i.)

These are the Teutonic nations that founded permanent kingdoms within the limits of the Roman empire. Except the Alemanni, they all came in contact with a population the educated part of which was entirely Romanised, although, except Italy and some parts of the south of Spain and Gaul, the inhabitants of the villages were still Celts or Iberians when they were subjugated by the Teutonic invaders. (Fauriel, 'Hist. de la Gaule Méridionale,' vol. i.) The political institutions of the new masters of the civilised world rested on two great principles.

The Teutonic laws were not territorial, as they now are, but personal: a Frank was judged after the Frankish law, a Burgundian after the Burgundian, wherever he lived. This principle being applied also to the Romans, gave rise to a double legislation, one for the ruling Teutonic nation, and the other for the subject Romans. The second principle was that the sovereignty belonged to the body of the conquerors, and not exclusively to their kings. This sovereignty not only comprised the supreme authority in legislation and administration, but it was considered as comprehending a right to the private landed property of the vanquished nation. Every free Frank or Goth became the master of a considerable portion of land which he took from the Romans. The rights and duties of the kings towards their Teutonic fellow-conquerors remained the same as before; the kings had no right to punish any freeman, unless in time of war and for neglect of military duties. The freemen also could not be forced to serve in any war to which they had not given their consent; and they did not pay any taxes to their kings, who were only the first among their equals. As to the subject Romans, the Teutonic kings became the lords of a numerous civilised nation: as successors to the rights of the Roman emperors, and with regard to the Romans, they had absolute power, and they became proprietors of the extensive private estates of the emperors. They maintained the provincial administration, which was established by Constantine the Great and his successors, but they often conferred various functions on one person in order to render that complicated administration more easy to manage. As the conquerors lived among the subject people, each province had a double administration, one for the ruling nation and the other for the subject nation. But there resulted so much confusion from this circumstance, that the kings were obliged, especially in Gaul, to sacrifice the principles of the Roman administration, and to govern in the Teutonic way, although the names of the higher public functions were Roman. The first functionary in each province in the Frankish kingdom was the Dux, who had the supreme military command, and sometimes also the authority of a judge. The second was the Comes, who was chief judge and director of all affairs concerning taxes and the revenue of the fiscus. From the 8th century the functions of the Dux and the Comes were conferred upon one person, who is sometimes styled Dux, and sometimes Comes.

The fate of the Romans in the Frankish empire was threefold. One part of the Romans entered into the private service of the king, and preserved a portion of their estates on condition of obedience to him. The great landowners belonged to this class, which had the name of "Romani convivæ regis." A second part, the "Romani possessores," remained in possession of their lands, but they were obliged to pay taxes for them, a duty from which the conquerors were exempt: this class principally consisted of small landowners. The third class were the "Romani tributarii," who lost their liberty, although they did not become Servi in the Roman sense of the word: these were the ancient "coloni." In many towns the Romans continued to enjoy their municipal institutions, while a Teutonic community gradually arose within the same walls, and had its separate constitution. In other towns the richest among the Romans lost their liberty and became "ministeriales," a kind of privileged vassals; but the poor were treated as the Romani tributarii in the villages.

The Teutonic nations which became subject to the Frankish kings were treated with less severity. The Burgundians, the Longobards, and the Bavarians only changed their dynasty, but the greater part of the Thuringians and of the Alemanni lost a considerable portion of their lands, which were given to Frankish nobles, of whom they became vassals.

Besides those nations which founded permanent kingdoms within the Roman empire, many tribes maintained their independence there only for a short period, or came and went rapidly without leaving further traces, or were subjugated by others, and adopted the names of their vanquishers. Many among them were of Slavonian or other origin.

The *Alani* came from the Caucasus, traversed Europe, and lived independent in southern Spain under their king Respendial, from 409 to 417, when they were subjugated by the Visi-Goths and carried into the south of Gaul. Another part of them settled between Orleans and Nantes under their chief Goar (406), but in 452 they were defeated and dispersed by the Visi-Goths. The Alani were not of Teutonic origin; the names of their kings (Respendial, Utaces, Goar) have no resemblance to Saxon, Frankish, or Gothic names. They are probably identical with the Ossetes, an old Persian tribe in the central part of the Caucasus. The country of Albania, north of the Caucasus, was known to the Greeks and Romans. The Byzantines called the tract between the Terek and Shirwan, Alania. (Procopius, 'De Bello Goth.,' l. iv.; Stritter, 'Memoriæ Populor,'—Alania, in tom. iv.; Suhm, 'Geschichte der Dänen,' übersetzt von Gräter, i. 1; Zeuss, 'Urgeschichte der Deutschen,'—Alanen.)

The *Quadi*, who lived in Silesia and Moravia in 375, were a Suevian people. The *Gepidæ* perhaps were of Gothic origin; their kingdom in Transylvania was destroyed by Alboin, who killed Kunimund, the last king of the Gepidæ.

Odoacer, the commander of a band of *Scyrri* or *Scirri*, *Rugii*, and *Heruli*, put an end to the Roman empire in Italy, and was acknowledged as emperor, but he was put to death by order of Theodoric the Great in 493.

The *Rugii* were Germani; the origin of the *Scyrri* and of the *Heruli* is uncertain. It has been pretended that the Heruli were a Lithuanian tribe.

Tribes within the limits of Germany which lost their independence under the Franks.—The *Bojoarii*, *Bojobari*, *Bajuvarii*, or *Bavarians*, whose name became known towards the year 480, were a confederation of Suevian tribes: they lived between the Danube, the Lech, and the Ens. In 540 they were forced to yield to the Frankish kings, and were governed by dukes of the dynasty of the Agilolfingians. Their laws, which were collected between 613 and 638, resemble the laws of the Alemanni, though they contain many traces of the Roman law. (Mederer, 'Leges Bajuvariorum, oder ältestes Gesetzbuch der Bajuvarier,' &c., 1793-8.) The *Thuringians* occupied the country north of the Bavarians as far as the Unstrut, and even beyond that river. They were related to the Goths, and their name seems to resemble that of the Thervingi, the Hermunduri, and Hermiones. Their last king, Hermanfrid, was deprived of his crown by the Franks in 531. Charlemagne is said to have made the first collection of their laws, but there is no evidence in support of this statement. Their code is known under the title of 'Lex Angliorum et Werinorum, hoc est Thuringorum.' These Angles and Warini or Werini were settled in the northern part of Thuringia, but it does not appear why their names are mentioned before that of the Thuringians, who were the more numerous nation. This collection is brief and incomplete. (Leibnitz, 'Script. Rer. Brunsvic.,' i.)

The *Saxons* dwelt north of the Thuringians. On the east their frontiers were the Elbe, the Stecknitz, and the Baltic; on the north, Denmark, the German Ocean, and Friesland; on the west, they corresponded to the western frontiers of the present province of Westphalia. When they had sent numerous settlers to Britain, their power became less formidable to their neighbours—the Wends in the east, and the Franks in the west. The Franks were formerly united with them against the Romans, but when they had conquered Gaul, the Saxons were obliged to desist from their incursions into this country, and hence arose jealousy and hostility. The south-western parts were conquered by the Franks as early as 555; the rich landowners were compelled to give a considerable part of their lands to Frankish nobles, and the common freemen to bend under the yoke of servitude. The remaining and greater part of the population was free, though from time to time the Saxons paid tribute, until, after the memorable war with Duke Wittekind (772-803), Charlemagne became master of all Saxony. But the Saxons were not subjugated like the Romans. They promised to adopt Christianity, to acknowledge Charles as their king, and to obey his governors (greves) and bishops. On the other hand, Charles granted them equal "Wehre" (value of their body and liberty in case of wounds, murder, &c.), and the same privileges which the Franks had, especially freedom from tribute, and the privilege of being tried in their own country, according to their own laws, and by their equals. (Leibnitz, 'Script. Rer. Brunsv.,' i.; Compare Möser, 'Osnabrückische Geschichte,' i.)

Charlemagne was the first king of the Saxons who formed a great confederation of free communities; they appointed dukes for their wars, and only acknowledged obedience to the "gowding" and to "greves" chosen by the freemen among the "edelings" of the communities. The laws of the Saxons were collected by order of Charlemagne. They consist of nineteen titles, and are so short and incomplete as to justify the opinion that only a part of them has been preserved. Two "Capitularia" of Charlemagne concern the political and ecclesiastical condition of those parts of Saxony which were conquered at the time of their publication (788 and 797). This 'Lex Saxonum' must not be confounded with the 'Sachsen-Spiegel,' the 'Mirror of the Saxons,' a code of Saxon law which was written in Latin, and afterwards translated into the Saxon language by Eicke van Rebgow, between 1215 and 1218. (Gärtner, 'Saxonum Leges Tres. Accessit Lex Frisionum,' 1730-4.)

Frisians. [Frisians.]—The laws of the Frisians were collected by Charlemagne under the title of 'Lex Frisionum.' (Gärtner, 'Saxonum Leges Tres. Accessit Lex Frisionum.') The 'Statuta Opstalbomica,' the laws of the Seven Sealands, which are written in the Frisian language, are a different collection. The dialect of this language, which most resembles the Anglo-Saxon language, is that of the northern Frisian islands on the coast of Sleswig.

Anglo-Saxons.—An account of their history has been given under Saxons; and under England in Geog. Div. The first settlement of Teutonic tribes in Great Britain previous to the arrival of the Anglo-Saxons, has been treated with great learning by Dr. Clement, in his work 'Die Nordgermanische Welt,' Copenhagen, 1840; and much valuable information respecting their laws and social habits will be found in Kemble's 'Saxons in England,' and the works of Palgrave and other recent writers on Anglo-Saxon history.

The following works contain full information concerning the history of the Teutonic nations:—Mascov, 'The History of the Antient Germans,' translated by Thomas Lediard; Gibbon, 'Decline and Fall;' Eichhorn, 'Deutsche Staats-und Rechts-Geschichte;' Savigny, 'Geschichte des Romischen Rechtes im Mittelalter;' Grimm, 'Deutsche Rechts-Alterthümer;' and his 'Deutsche Grammatik.'

The Scandinavian branch of the Teutonic nations appears late in history. The Sagas tell us that in the fifth century B.C. Odin led the Scandinavians to Sweden and Norway; but this Odin is a god. Less fabulous is the history of a second Odin, who, in the beginning of our era, came from Asia to Scandinavia, accompanied by his "Asen" or perhaps "Ansen," or fellow-warriors. The name of the Suiones or Swedes was known to Pliny and to Tacitus, and Pliny knew the name of Scandia, now Scania, the southern extremity of Sweden, which name gradually acquired its present general meaning. Goths came to Scandinavia at a very early period, and the second Odin was perhaps their chief. They mixed with the Scandinavians, and traces of their language have been found in the dialects of the provinces of East and West Gothland in Sweden, and their name is still preserved in many localities. The aborigines of Sweden and Norway belonged to the Finnish race. They fled towards the north, but not without leaving their traces in the mountains of the Kjœlen and the Dovre Fjeld.

The Scandinavians, Northmen, or Normans, became known to the southern nations by their piracies, and they were often leagued with the Saxons. In the wars between Charlemagne and Wittekind, the Danes assisted Wittekind, who had married Gera, the daughter of their king, Siegfried. As early as the beginning of the 8th century the Danes and Jutes appeared in the north of England; in the beginning of the 9th century the Danes settled on the south-east coast of Ireland. Normans or Norwegians occupied the Orkneys before the end of the 9th century: in 861 they came to the Farœ Islands, and they sent colonies to Iceland as early as 870. The northern parts of North America were known to these bold navigators four centuries before the time of Columbus. Other Normans conquered Normandy, Apulia, Sicily, and the opposite coast of Africa. From the 8th century the Waregians, who came from Norway and Sweden, penetrated into Russia, and founded the Norman dynasty of the grand-dukes of Kiew. Some of the first families of the Russian nobility are of Norman origin.

The Swedes conquered the coast of Finland as early as 850, and settled in great numbers in the districts of Abo and Nyland. Although Finland is chiefly inhabited by a nation of Finnish origin, and though it has become a Russian province, the Swedish language is the only language used for public acts and legal documents.

Suhm is one of the best authorities for the critical history of the Scandinavians. He has written in Danish on the origin of the Scandinavians, on their mythology, a critical history of Denmark, a history of Denmark, and several other works concerning this country.

(Müller, in his 'Kritisches Examen der Dänischen und Norwegischen Sagengeschichte,' examines the historical truth of the Sagas; Peringskjöld, 'Monumenta Sueo-Gothica,' Stockholm, 1710, fol.; Peringskjöld, 'Wilkina Saga, sive Historia Wilkinensium,' contains an account of the exploits and conquests of the Scandinavians in Russia, Italy, &c.)

Table of the modern Teutonic Languages and their Dialects.

I. High German Languages.

(The German language as it is written or spoken by the well-educated Germans, belongs to the High German languages, but is not a dialect.)

A. *Suabian* branch.

a. Suabian, subordinate branch, containing the dialects of
1, *Suabia*, that is, of the Black Forest, of the Neckar, and of the country between the Danube and the Lech.
2, *Bavaria*, that is, of the Alps, of Salzburg, and of the Danube.
3, *Tyrol*, that is, of Vorarlberg, of the Inn, of the Etsch (Adige), and of the Puster-Thal.
4, *Austria*, that is, of the archduchy of Austria, of Styria, of Carinthia, of Carniola, of Southern Bohemia, and of Moravia.

b, Alemannic, subordinate branch.
1, *Alemannic*, commonly so called in the south-west corner of the Black Forest.
2, Dialects of Switzerland, that is, of Bern, of the Oberland of Bern, of Wallis, of the country of the Grisons, and of Appenzell, &c.
3, Dialects of Elsass (Alsace), and of Baden.

c. Old Thüringian, subordinate branch, containing the dialects of the Thüringer Wald, of part of the Fichtelgebirge, and of the northern part of the Böhmerwald. These dialects are generally confounded with those of the adjacent flat countries of Thüringia and the Upper Palatinate, which belong to the Franconian branch.

B. *Franconian* branch.

1, Dialects of Franconia, of the Palatinate, of the Middle Rhine, and of Southern Hesse.
2, Dialects of Thüringia, except the Thüringer Wald, of Northern Hesse, and of the Eichsfeld.
3, Dialects of Lorraine and Luxemburg, which are much mixed with Low German.
4, Dialects of Upper Saxony, of Meissen, of the Erzgebirge, and of Lusatia.
5, Dialects of Northern Bohemia, of Silesia, and of part of the German colonies in Hungary.
6, Dialects of the nobles, the clergy, and the citizens in Curland, Livonia, and Esthonia.

II. Saxon Languages.

A. *Frisian* branch, which contains the dialects of West Friesland, of Saterland, of the islands along the Dutch and the German coast, and of the islands along the coast of Sleswig.

B. *Low German* branch, divided into six sections, namely:—
1, Of *Lower Saxony*, containing the dialects of Sleswig, of Holstein, of Hamburg, of Bremen, of Brunswick, of Hanover, of the country between the Harz and the Weser, and of the Marshes with East Frisia.
2, Of *Westphalia*, with the dialects of Upper Münsterland, of Lower Münsterland, of Osnabrück, of the Upper Weser, of Sauerland, of Mark, and of Eastern Berg.
3, Of the *Lower Rhine* between Neuwied and Düsseldorf, especially the dialects of the Eifel, of Cologne, and of Aix-la-Chapelle.
4, Of the *Netherlands*, containing the Dutch language, the Flemish language, and the dialects of Jülich, of Cleve, and of Geldern in Germany.
5, The dialect of the Saxons in *Transylvania*.
6, Of the ancient *Wendish* countries, colonised by the Saxons, containing the dialects of Mecklenburg, of Pomerania, of Brandenburg, of the Marks, and of East Prussia.

C. *English* branch. [Saxon Language and Literature; England, in Geog. Div.]

III. Scandinavian Languages.

A. *Old Norman* branch, containing the dialects of the mountaineers of Norway, the Icelandic language, and the idiom of the Farœ Islands.

B. *Danish* branch, containing the Danish language, with the dialects of the islands, of Jutland, and of Northern Sleswig, and the modern Norwegian language.

C. *Swedish* branch, containing the Swedish language, with the dialects of Gothland, of Dalecarlia, of Stockholm and the adjacent country, of Finland, and of the Aland Islands.

(Adelung und Vater, 'Mithridates;' Balbi, 'Atlas Ethnographique;' Ober-Müller, 'Atlas Ethno-géographique de l'Europe.')

TEXTILE MANUFACTURES. [Cotton.]

THAMES, a certain jurisdiction, though not undisputedly exclusive, appears to have been immemorially exercised over both the fisheries and navigation of a large portion of the Thames by the mayor and corporation of London. In early times, when fisheries were probably of much greater importance than they are at present, the same kind of encroachments upon them by private individuals which were so often made the subject of complaint in other parts of the kingdom were also practised in this river. In 1405 an order was issued from Sir John Woodcock, then lord mayor, enjoining the destruction of wears and nets from Staines to the Medway, in consequence of the injury which they did to the fishery and their obstruction of the navigation. By 4 Hen. VII., c. 15 (1487), the mayor of London and his successors were invested with the same authority as conservator of the fish in "all the issues, breaches, and ground overflown as far as the water ebbeth and floweth from out of the river Thames," as he had within the river itself. Before the river was artificially embanked and the adjoining lands drained, this extension was probably of considerable importance. During the reign of Elizabeth, in 1584, an order was put forth by the mayor for the purpose of settling the proper times in which various kinds of fish were to be taken. It prohibited fishing in certain parts of the river, and forbade the taking of the white-bait or "bloodbag." The right of the corporation, however, to the conservation of the river about this time was disputed by the lord-high-admiral, and some litigation took place, in which the corporation was uniformly successful. James I. in the third year of his reign granted a charter to the city, in which the immemorial right of the city to the office of bailiff and conservator of the Thames is recited and confirmed. The same rights are also confirmed and settled by various other charters and acts of parliament. The result was to vest in the corporation the conservation of the river, the regulation of the port and harbour of London, and, as is said, the actual property in the soil of the river, subject only to the jus regium of the crown. The commencement of the city's jurisdiction was marked by a stone, with an apocryphal date, called London Stone, placed on the north bank of the river, a short distance above the present bridge of Staines, and its termination on the south shore, by the formerly navigable creek of Yantlet, separating the Isle of Grain from the mainland of Kent, and on the north shore by the village of Leigh, in Essex, placed directly opposite, and close to the lower extremity of Canvey Island, thus extending a distance of eighty miles, over nearly the entire course of that river through the metropolitan valley.

After much litigation between the City of London and the Crown, the conservancy of the river, which involves the control of the fisheries, the regulation and control of the watermen and of the shipping, the cleansing of the river, the removal of obstructions, erection of stairs, licensing mills, and other such duties, has been vested, by act of parliament, in a Board of Conservancy, to whom the powers of the corporation have been transferred.

(Griffiths, *Conservancy of the River Thames*; Stow, *Survey of London*; Pulling, *On the Laws, &c. of the City and Port of London.*)

THAMMUZ, in Hebrew תַּמּוּז, is the tenth month of the Jewish civil year, coinciding with our June or July; it has twenty-nine days, and in the present year (1861), it will begin on the 9th of June and end on the 7th of July. The name does not occur in the Bible, as a month at least; the passage in Ezekiel viii. 14, "women weeping for Tammuz," having no known connection with the month. Benfey, who has a short dissertation on the name in his 'Monatonamen,' p. 164, seq., denies the identity of Thammuz and Adonis, first advanced by St. Jerome in his commentary on Ezekiel. In the copies of the calendar of Heliopolis the name is written *Θαμιζα*, *Θαμμουζ*, and *Θαμα*. A fast is kept on the 17th day of Thammuz, in memory of the capture of Jerusalem by Titus, according to most authorities, though some say it was instituted to commemorate the breaking of the Tables of the Law by Moses, Exod. xxxii. 19. In some calendars a feast is mentioned on the 14th day, to celebrate the destruction of a pernicious book tending to discredit the traditions of the Rabbins. In the Syrian calendar now in use, Thamuz is the fourth month, as it was among the Hebrews when the year began with Nisan.

THANE, in Anglo-Saxon *thegn*, from *thegnian*, or *thenian*, "to serve," the same word with the modern German *dienen*, is frequently, in conformity with this origin, translated *minister* in the Latin charters of the Anglo-Saxon period. In other cases its equivalent is *miles*, or *fidelis miles*. So king Alfred, in his translation of Bede's 'Ecclesiastical History,' renders the king's minister, the king's thane, and uses thane wherever Bede has *miles*. The exact meaning of the term when employed as a title of honour is involved in considerable obscurity: the rank or dignity which it denoted was possibly not the same at different times, and there were also thanes of more than one kind. After the Conquest thanes (*thaini* or *taini*) are frequently classed with barons (barones): in the laws of Henry I., the two words are apparently used as synonymous; and where the Saxon Chronicler has thanes (*thegenas*), the Latin annalists have commonly *barones*. The class of common or inferior thanes seems to have answered nearly to that of the barones minores, or landed gentry. One of the few things that are tolerably certain with regard to the rank of a thane is, that it implied the possession of a certain amount of landed property. Such a qualification indeed seems in certain circumstances to have conferred the dignity of thane. One of the laws of Athelstane declares that if a ceorl (or commoner) shall have obtained five hides of land in full property, with a church, a kitchen, a bell-house, a burghate seat (or office of magistrate in a burgh), and a station in the king's hall (the meaning of which last expression is doubtful), he shall henceforth be a thane by right. Five hides of land was probably the amount demanded even for a thane of the highest order; although it appears from Domesday-Book that this was also the quantity which made the owner a miles, or liable to be called out on the king's military service. Many lands are mentioned in Domesday-Book as thane-lands (terræ tainorum); and it is probable that the dignity, like the oldest of the Norman baronies, was sometimes attached to a particular estate. Thanes were among the members of the Saxon Witenagemot, or parliament. The principal facts connected with this dignity in England have been collected by Mr. Sharon Turner, in his 'History of the Anglo-Saxons,' 8vo., London, 1823, vol. iii.; by Sir Francis Palgrave, in his 'Rise and Progress of the English Commonwealth,' 4to., 1832, and by Mr. J. M. Kemble in his 'Saxons in England,' 1849.

There is little mention of the thanes in England after the time of Henry II.; but Lord Hailes has shown ('Annals,' i. 28) that in Scotland thane was a recognised title down to the end of the 15th century: the 'Chartulary of Moray' mentions a thane of Cawdor in 1492. It appears from the first to have implied in Scotland a higher dignity than in England, and to have been for the most synonymous with earl, which was a title generally annexed to the territory of a whole county.

THAW is the reduction of ice or snow to a liquid state in consequence of an increase in temperature. In the ordinary succession of the seasons, this effect is produced on the surface of the earth or in the atmosphere during the spring by the return of the sun to the hemisphere of the observer, the solar rays then falling in greater abundance than before on a given extent of ground; or it is produced by accidental currents of warm air which pass over a frozen mass. The dissolution of particles of ice or snow floating in the atmosphere, and the universal liberation of moisture previously frozen up, are the causes of the humidity which accompanies a thaw.

As the conversion of a liquid into ice always commences at the surface of the former, and about the sides of the vessel containing it, or about those of a solid body immersed in it, so in ice surrounded by air which has acquired a higher temperature than the ice has, the process of liquefaction commences at the sides and extends gradually from thence inwards; ice being a bad conductor of heat, the central parts of it, under ordinary circumstances, are the last which are dissolved. It is observed that when solid bodies, whose temperatures are equal to one another and higher than that of ice, are applied to the latter, the ice is dissolved most rapidly by those which have the greatest power of conducting caloric: thus a piece of ice being laid on a plate of polished metal, and a piece of equal magnitude on wood, the ice on the metal will be dissolved before that which is laid on the wood, not only when the temperature of the metal and wood are equal, but even when the temperature of the wood considerably exceeds that of the metal, the latter conveying more abundantly to the ice the caloric which it is continually receiving from the atmosphere.

A severe and long-continued frost abstracts so much caloric from terrestrial bodies, as the walls of buildings which are not exposed to the sun, that these are often cooled below the temperature of freezing water; and while in this state, if a current of warm air pass over their surfaces, the aqueous vapour which the air contains deposits itself on the walls, where it is converted into ice or snow: it remains thus frozen for a time after a thaw has commenced, but at length, the temperature increasing, the ice is melted and the walls are then covered with moisture.

It is often remarked that, at the time of a thaw taking place, there is felt a degree of coldness greater than that which is experienced during the continuance of the frost; this has sometimes been ascribed merely to the evaporation of the moisture which is then on the skin, as the thermometer at the same time indicates an elevation of temperature in the atmosphere. But the evaporative power of the skin must depend both upon the temperature of the air and the amount of aqueous vapour which it already contains, and in part also on the local heat of the human body. The sensation alluded to arises, in all probability, from the continual conversion of the sensible heat of the atmosphere and the surface of the earth and bodies resting upon it, into a latent form during the process of thawing, the latent heat of water being greater than that of any other substance. Dr. Faraday has shown that the conversion of a cubic yard of ice simply into water at 32°, or ice-cold, would absorb or render latent the whole heat emitted during the combustion of a bushel of coal. [HAIL; ICE; WATER.] The amount of heat thus required in the liquefaction of ice renders a thaw so gradual. This is an important provision of nature; but for it, "the ice that had accumulated during a long winter would at the first breeze from the south be instantly converted into water, and sweep before it, not merely the habitations of man and their tenants, but trees, rocks, and hills;" every thaw, in fact, would occasion a frightful inundation. Conversely, frost is rendered gradual by the evolution of the latent heat of water in a sensible form.

For a remarkable case of slow thawing, and illustration of the principle on which the gradual nature of that process depends, we may refer to some experiments made by Dr. Faraday for the investigation of a different subject, that of regelation. He prepared a bath of water, which could be retained, by appropriate contrivances, at the unchanging temperature of 32° Fahr., or the melting-point of ice, for a week or more; but a small piece of ice floating in it for that time was not entirely melted away. Yet the temperature was adequate to the liquefaction of ice, for a very slow thawing process was really going on in the bath during the whole time, as was rendered evident by the state of this very piece of ice; but the glass jar containing the water being surrounded by a system of bad conductors of heat, including dry flannel and broken ice, the heat of the atmosphere and exterior surrounding bodies could only very slowly penetrate to the ice in the bath, and there supply the heat required to become latent in the process of thawing it, and hence the rate of thawing was so slow as not to dissolve a cubic inch of ice in six or seven days. (See 'Proc. of Royal Society' for April 26, 1860, vol. x., pp. 442, 449.)

A phenomenon observed at Inspruck, in the Tyrol, which has been referred to the contrary operation of local winds, probably admits of explanation upon the principle of the absorption or rendering latent of heat in the thawing process. At that place the snow is often seen melting on the mountains above the town, at an elevation of 3000 feet, while it continues very cold and there is not the least sign of thaw in the valley of the river Inn below. It is then popularly said that the south wind is driving the cold into the valley; and this saying seems to involve the truth. The air above will be greatly cooled down by the abstraction of its heat in the melting of the snow, and, thus becoming heavier, will descend in the atmosphere and maintain for a time the low temperature in the valley below.

The overflowing of rivers by the dissolution of the snow and ice on the mountains above their sources is well known [RIVERS, col. 119], and to the liquefaction of the ice formed by the previous congelation of water which has introduced itself into the fissures of rocks is to be ascribed the occasional severance of large masses from the sides of mountains; the expansion of the water in freezing having destroyed the cohesion, so that the parts are only held together by the ice, and on the liquefaction of this the disunion is complete.

Two pieces of thawing ice, if brought into contact, adhere and become one; at a place where liquefaction was proceeding, congelation suddenly occurs. This is the phenomenon and process of *regelation*, already treated of in the article ICE. The view of the thawing or melting of ice taken by M. Person, that it is a gradual process, resembling that of wax and metals, and not really a sudden one, and its adoption by Professor James Forbes, as well as the objections to it urged by Professor James Thomson, have been noticed in the article ICE. Person's original paper, 'On the Latent Heat of Fusion of Ice,' will be found in the 'Comptes Rendus' of the Royal Academy of Sciences of Paris, for April 29, 1850, vol. xxx., p. 526. The evidence he adduces of the supposed viscosity of ice, intermediate between the states of rigid solidity and perfect fluidity, consists solely of an amount of latent heat which a high authority agrees with us in considering to be much within the probable errors of the delicate experiments required. The application made by Professor Tyndall of the principle of regelation, renders the plasticity of ice in the mass quite intelligible, without the necessity of attributing a viscous property to that substance, the existence of which is negatived by all the other properties which it possesses.

Although the terms thawing and freezing were originally applied only to the solidification and re-liquefaction of water, by variations of temperature, and derivatively to those of other fluids in ordinary use, their sense has become extended in the progress of that more precise knowledge of natural things which is called science, to denote also, generally, the solidification and re-liquefaction of liquids not commonly observed in the solid condition. We speak, for example, of the freezing and thawing of mercury; and not only so, but the terms thawing and freezing are sometimes used to express the circumstances of the melting and re-solidification of bodies which are ordinarily solid—solid, that is, at common temperatures, an expression which, as usually employed, includes a considerable thermometric range from above the freezing to below the boiling point of water, and is even extended, though indefinitely, somewhat below the former and considerably above the latter, though not to a red heat, or a temperature at which light is evolved. Thus these terms have been applied to the melting and crystallisation of glass. In like manner, the term fusion, originally employed with reference to the liquefaction of bodies which are solid at common or much higher temperatures, has come to be applied, as equivalent to that of thawing, to the melting after solidification of substances which are ordinarily liquid. In this manner we speak of the fusion of ice, as well as that of wax or of copper; and Dr. Faraday has described, in the paper referred to above, an experiment in which layers of ice are produced "of greater and less fusibility."

THEA. [TEA.]

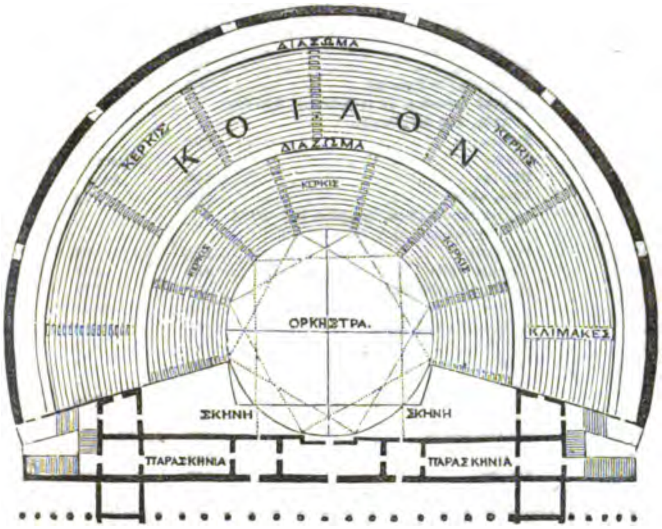
THEATINS, or TEATINS, an order of monks founded at Rome in 1524, principally by Gianpietro Caraffa, who was then archbishop of Chieti, in Naples, the Latin name of which is Teate, and who afterwards became pope under the title of Paul IV. The institution was confirmed at the time of its foundation by the reigning pope, Clement VII.; and a final rule, or code of regulations, drawn up by a general chapter of the order, was authorised by Clement VIII. in 1604. The Theatins were principally established in Italy and in France, into which latter country they were brought in 1644, and where they subsisted till the Revolution of 1789. Their dress was a black cloak and cassock with white sleeves; and the principal peculiarity of their institution was that they affected to subsist not only upon alms, but upon alms bestowed upon them without being asked for. They procured, however, considerable support in this way, and they were at one time enabled to maintain missions in Georgia, Circassia, Mingrelia, and other parts of Asia. Their history has been written by John Baptist Tuffins, under the title of 'Annales Theatinorum.' There were also Theatin nuns (in French, *Theatines*), so called from having been placed by Pope Gregory XV. under the direction of the Theatin monks, their original and proper designation having been Sisters of the Immaculate Conception. A notice of a controversy between the Theatins and the Jesuits, which was kept up for a great part of the 17th century, is given by Bayle, in a note to his article on 'Ignatius Loyola.'

THEATRE (from the Latin *theátrum*, which is from the Greek *θεάτρον*, 'a place for seeing'), a word adopted in all modern languages to signify a building appropriated to dramatic representations. The oldest edifices of this class are those of the Greeks and Romans, for it was with them that the European drama originated, and, in point of magnitude, the Greek and Roman theatres surpassed the most spacious of their temples. The enormous extent of many of the ancient theatres, and the prodigious solidity of their construction, are attested by the numerous remains of such edifices, which have been explored not only in Greece and Italy, but also in Asia Minor. Of some of them indeed little can now be traced, but others are sufficiently perfect to convey a clear idea of the arrangement and general appearance of the structure in its original state; that is, however, merely as regards the space appropriated to the spectators, for scarcely anything remains to explain what is most difficult, and, as regards the dramatic exhibitions, most important of all to understand, namely, the stage itself, including under that term the whole space requisite for the accommodation of the performers, and for the preparation of the exhibition before the audience. Owing to the want of any evidence of the kind afforded by the buildings themselves, and to the very little that can now be gathered from the scanty notices of ancient writers, we have no certain knowledge of many things which now can only be conjectured. The character of the performance has been spoken of under DRAMA.

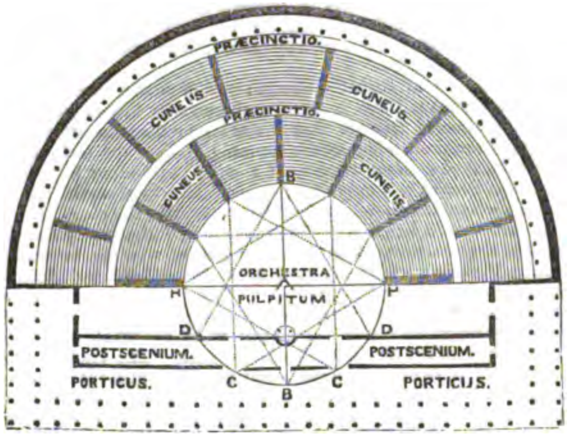
The circumstances that are mentioned for our admiration, and as proofs of the magnificence and sumptuousness of some of the ancient theatres, prove how deficient in scenic illusion and stage effect the performances must have been. Whether it be at all exaggerated or not, it is evident from what Pliny ('Nat. Hist.,' xxxvi., c. 15) says of the theatre of Scaurus, at Rome, that the *scena* was a mere architectural façade, unmeaning in itself, though lavishly embellished with marble columns and statues—with no fewer than 360 of the former, arranged in three tiers, and 3000 of the latter, a most incredible number, surpassing that of a modern audience. Pliny puzzles us still more when he says that the middle of the scena (meaning the second of the three orders) was of glass, "*vitro*." The actors it is evident must have appeared mere pigmies upon a stage of such enormous extent, with a number of statues behind them. This must always have been in some degree the case, since even in moderate-sized ancient theatres the stage was enormously wide in comparison with what it is in the very largest modern theatres. The scena too was always a permanent architectural erection, incapable of change. It has been supposed that, besides the permanent scena, the ancients employed, occasionally at least, moveable painted scenes, capable of being let down before it. Yet while this can be only vaguely inferred, the presumption against it is founded both on its impracticability and its extreme improbability. If they even did, as some suppose, practise scene-painting, it is scarcely conceivable that they should have had painted moveable scenes on canvas, which on the average must have been 200 feet in width, especially where the stage itself was so shallow and confined at its sides, and without any space for apparatus or machinery over it. Vitruvius does indeed mention, in the proem to his seventh book, Agatharchus as a scene-painter, and Democritus and Anaxagoras as writers on scenography and perspective; but it is with such vagueness of expression, that it is difficult to draw any conclusion from his words. Of the former he merely says "scenam fecit," which probably means no more than that he was one of the first who introduced some sort of decoration on the scena, or back wall of the stage, where, if there was at any time painting at all, it could only have been very partial, and as accessory embellishment to that general façade. The fixed arrangement of the scena itself, with three distinct entrances assigned to the performers according to their rank in the piece, the centre one being for the principal characters, the others for those supposed to arrive on one side from the port, on the other from the country, was not only an awkward conventionalism in itself, but an expedient which shows how imperfect the ancient stage must have been, notwithstanding its alleged magnificence. What there was of painted scenery at all was probably confined to two *Versuræ* (*περίακτοι*) at the sides or ends of the stage, which served as "wings," and which were upright triangular frames made to revolve upon a central pivot, so that any of the three sides could be turned towards the audience; a very scanty change of scenery at the best, and only sufficient to *hint* where the action was supposed to take place.

From the use of the term *Aulæa* it has been generally concluded that the whole stage was concealed by a curtain, both previous to the commencement of the performance and whenever it was requisite to make any change in the decorations. But we agree with Winckelmann, that such could not possibly have been the case, because in the first place it could hardly have been practicable, and in the next it was unnecessary as regarded the permanent scena or architectural façade. But even admitting that there was painted scenery, and that it was not inferior to that of our own theatres, either in regard to truth of perspective or to anything else, it still must have fallen far short of the latter in effect, if only for the reason that the performances took place by daylight. At the best the illusion could have been but exceedingly imperfect—a strange mixture of the artificial with the real. The natural lights and shadows and the painted ones must frequently have been in contradiction to each other; nor was it possible to manage any effects of light, as in our theatres, by either increasing or diminishing it, or by concentrating it on any particular part of the scenery. The only thing in favour of the ancient stage in this respect, is that there were no "foot-lights," and consequently the faces of the performers were not lighted from beneath. Yet even this comparatively unimportant advantage was nullified by the use of masks, some of them so extravagant as to bear scarcely any resemblance to the human countenance, whilst in all a fixed expression of countenance was substituted for what could properly be only a momentary one. This was however of the less consequence, because, owing to the vast extent of the theatres, the faces of the actors could hardly have been distinctly seen, or even seen at all by the great majority of the spectators. The whole space was so great, that in regard to it the actors could have been little more than as the figures put by a painter into a landscape.

On considering the audience part, and the accommodation provided for the spectators, although there the arrangement of an ancient theatre was nearly perfect, and in some respects preferable to that of modern ones, it was not free from many inconveniences. The most obvious one is, that as there was no roof, there was no shelter from the weather, on which account awnings were sometimes made use of to screen from the heat of the sun, while in case of sudden and heavy rain the spectators were obliged to take shelter in the corridors behind and beneath the seats, where there were any, and in the porticos at the back of the theatre. Besides interruption to the performance, this must have occasioned considerable confusion in so numerous an assemblage of persons. Beautiful too as the arrangement of all the seats in concentric rows is in itself, it is attended with some disadvantage, as will be perceived on referring to the annexed plans, for instead of being placed, as in the pit of a modern theatre, parallel to and immediately facing the stage, a considerable portion of the audience must have sat sideways to it, with part of it behind them; and those at the ends of the further or upper benches could hardly have had any view of the scena at all, at least not in the Greek theatre.



Greek Theatre.



Roman Theatre.

The Greek and Roman theatres so very nearly resemble each other in their general form and principal parts, that it is only by comparing the plans, for the purpose of seeing wherein they vary, that the difference between them can be clearly understood. Such difference however is exceedingly slight, the general arrangement and the essential parts being the same in both,—the *Coelum* (Κοῖλον), *Orchestra* ('Ορχήστρα), and *Scena* (Σκηνή) in the one, and the *Cavea*, *Orchestra*, and *Scena* in the other. The cavea was the general term for the whole of the space appropriated to the seats of the spectators, which were all concentric with the orchestra, and which were intersected, in one direction, by ascents or flights of steps (*κλίμακες*) dividing the seats into so many compartments, termed *κερκίδες*, or *Cunei*, and separated into two or more "flights" or "tiers" by broader spaces or landing-places, called *Διαζώματα*, or *Præcinctiones*. The number of the *κλίμακες*, or ascents, and that of the *Διαζώματα*, or Præcinctions, and also the breadth of the latter, appear to have been regulated entirely according to the extent of the theatre and other circumstances. In general there seems to have been only one Præcinction between the seats, dividing them into two "flights," not however so as to give an equal number of rows of seats to each. In the theatre near Epidaurus, for instance, there were 54 rows of seats, divided by a single Præcinction, and 34 of them formed the *first* or lowest tier nearest the orchestra; while in that at Syracuse there were 62 rows, with only a single Præcinction between them, and 41 were given to the *second* or upper flight, furthest from the orchestra. In the theatre at Dramyssus, again, there were two Præcinctions, dividing the entire number of rows, 54, into 18, 16, and 20 respectively, reckoning from the orchestra. As regards the distinct "flights," or series of seats, there were two modes of disposing them: the more usual one was to break into separate slopes, retiring from each other, like the "flights" in an ascent of steps; the other was to place them in a continued slope from the lowest to the highest seats, whereby at each præcinction the next "flight" was considerably elevated above the level of that landing, being raised upon a podium or wall, which showed itself between the lower and upper "flight." Besides the præcinctions *between* the seats, there was another surrounding the whole *coelum*, or auditory of the theatre, forming either an upper uncovered terrace as a standing-place for spectators, or a covered gallery with columns, as is shown in the plan of the Roman theatre, where such portico was assigned to females.

Between the Grecian and Roman orchestra there was a very wide difference as regards the purpose to which that space was appropriated. In the Roman theatre it was merely a continuation of the rest of the auditory, being occupied with seats and spectators, with no other difference than that the spectators were senators and other persons of dignity, and that benches or chairs must have been ranged parallel to the stage. The Greek orchestra, on the contrary, was, as its name imports, made use of for the dancers, musicians, and singers, whose performances constituted so important a part of the entertainment; and so far nothing could have been better planned than the Greek theatre, for the orchestra was visible from every part, whereas the scena could not have been distinctly seen, or hardly seen at all by those on the upper seats at either extremity of the coelum. By referring to the plans it will be seen that while the Roman orchestra does not exceed half a circle, the Greek forms three-fifths of one, or an arc of 216 degrees, its proportions and the depth of the stage being ascertained by merely inscribing a square within a circle, taking one side of that square as the boundary of the stage, and drawing parallel to it a tangent to the circle, which tangent coincides with the scena or back of the stage. Such plan therefore is simple enough, complex as it may appear in the cut, where two other squares are also drawn within the circle, and the points of the three squares determine how far the seats extend, and the situation of the steps (*κλίμακες*) between the seats,—a fanciful operation, nothing more being required after the first one than to divide the arc or curved portion of the orchestra into as many equal parts as would be requisite according to the number of ascents. In fact this last appears to have been the mode practised, for there are as many examples which differ from as agree with that established by Vitruvius for the Greek theatre. According to that, the divisions, the number of cunei and steps between them, would be uniformly the same, namely, seven of the former, and eight of the latter, including those next the stage, as shown in the cut. This however is so far from being the case, that very material differences occur in that respect. At Epidaurus, for instance, there are ten cunei in the lower tier, and eleven ascents, consequently an even number of the former and an odd one of the latter. At Dramyssus again there are nine cunei and ten ascents; and at Syracuse and Tauromenium the same. The Roman orchestra and scena were also defined by a circle, within which was inscribed an equilateral triangle, one of whose sides D D formed the scena, while the diameter H H of the circle, parallel to the scena, formed the boundary between the pulpitum or stage and the orchestra, the last being always a perfect semicircle. The other three triangles are merely for the purpose of determining the points where the scalæ, or steps between the cunei, are to be, for which nothing more is requisite than to divide the semicircle of the orchestra into as many equal parts as there are to be cunei, whether the number be six or any other; and the diameter of the orchestra H H being given, the distance of the scena from it would be ascertained by making it equal to one-fourth of that line. After all, as has been remarked by Wetter in his work on theatres, there is something more whimsical than rational in such an arrangement. In addition to the disadvantages already pointed out, as regards the want of moveable scenery, it was no slight inconvenience that the stage could never be occasionally extended in depth, shallow as it was. Taking 70 feet as the diameter of the orchestra alone, which dimensions are equal to the whole of the largest of our modern theatres, the depth of the stage in a Grecian theatre would be a little more than 10 feet, or one-seventh of that diameter; and in a Roman one 17¼ feet, or just one-fourth. While so confined a space would admit of very little dramatic action, it would scarcely admit of any change of scenery. Yet shallowness of the stage was in some measure matter of necessity, in order that the performers might be as near to the front of the stage as possible, separated as they were, in the Grecian theatre at least, from the audience by the intervening orchestra.

Strict as were the rules for proportioning the depth of the stage to the size of the orchestra, the relative size of the orchestra to the coelum or whole auditory does not appear to have been subject to any regulations: it varies considerably in different theatres, being in some nearly one-half, in others only one-fifth, or even little more than one-sixth of the entire diameter of the interior, as in the theatres of Epidaurus and Dramyssus, or Janina.

When it is said that the Grecian orchestra was considerably larger than the Roman, there is some ambiguity in the expression, for it might be inferred from it that it was larger than the other in proportion to the coelum, whereas the meaning is that the orchestra of the Greeks formed a larger portion of a circle, extending to 220 degrees, while the Roman was only 180 degrees, or an exact semicircle. In the Greek theatre, therefore, the orchestra cuts into the stage, and renders that part termed Logeion by the Greeks, and Pulpitum by the Romans, considerably narrower than the extremities, whereas in the Roman theatre the stage was of the same depth throughout, pulpitum being a mere technical distinction applied to that portion corresponding with the orchestra, and to which the actors confined themselves, in order that they might be better seen and heard by the whole of the audience than would otherwise have been the case. The ancients also had recourse to what seems a strange expedient for transmitting the actor's voice to the furthest part of the theatre, namely, that of placing in cavities for the purpose beneath the seats hollow metal or earthen vases, termed Echeia (ἠχεῖα), that is, "sounding thing," which augmented the sound. The plans above given are not drawn to any particular scale, but supposing them to be upon the same scale, and the diameter of the orchestra in the Greek plan to be 100 feet, the diameter of the coelum or whole auditory will be 300 feet, the width of the stage and scena 180 feet, and the depth of the logeion only 15 feet, while in the other the dimensions will be, orchestra 100 feet, auditory 270 feet, scena 195 feet, depth of stage and pulpitum 25 feet.

Another point of difference between the Grecian and Roman theatre is that in the former the stage was considerably elevated above the orchestra, 12 feet or upwards, consequently there was a wall of that height at the back of the orchestra, to which was given the name of Hyposcenium (ὑποσκήνιον), or Lower Scena, and which appears to have formed a sort of architectural basement to the stage, and was adorned with niches and statues.

Little more remains to be said on the subject of ancient theatres, except to remark that the form of the orchestra also determined that of the exterior of the building; while the Roman theatres, therefore, did not exceed a semicircle, those of Greece had a greater curve. In the Greek theatres, however, the orchestra was not always extended beyond a semicircle by the curve being continued, but sometimes by straight lines at right angles to the chord (or parallel to B B, in the plan of the Roman theatre, whose general form is so shaped, the external semicircle being prolonged by the colonnades). Grecian theatres were almost invariably built on the sloping side of a hill, so that, as regards the coelum, it was merely necessary to shape it out, and erect the seats; consequently there was no other architectural exterior than that formed by the Parascene (Παρασκήνη) and colonnade behind the stage; for which reason the degree of curvature did not manifest itself. The Roman theatres, on the contrary, were erected on level ground, and, therefore, the curved part of the exterior was confined to a semicircle, a form which unites better with the rectangular one and its straight lines.

The theatre at Athens (called that of Dionysus) was by no means so spacious as many others, its diameter being only 250 feet, and that of the orchestra 72 feet, which are very moderate dimensions in comparison with those of some of the Asiatic theatres. The Odeion of Regilla, also at Athens, though similar in its general plan to the usual theatre, was a music-hall, and was covered in with a tent-like roof, with a semicircular *eye* or opening for light. Both structures were situated at no great distance from each other on the south side of the Acropolis; therefore the scena of the theatre had a northern aspect, and must have been in shadow while the performances took place.

The following is a list of such ancient theatres as are known, together with the respective dimensions of their general diameter and of their orchestra; which we have for the most part taken upon the authority of a similar table given by Colonel Leake, in his 'Tour in Asia Minor,' to which several other examples are here added.

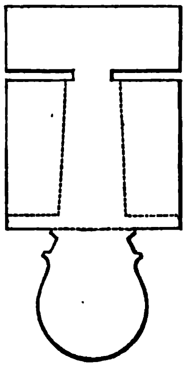
	Diam.	Orchestra.
Anemurium	197 feet.	
Aspendus (scena Ionic and Corinth.)	400	25 rows of seats.
Athens, Theatre of Bacchus	250	72 feet.
,, Odeion	90	36
Cnidus	400	
Delos	175	
Dramyssus, or Joannina	440	78
Ephesus	660	240
Epidaurus	370	55
Herculaneum	180	16 rows of seats.
Hierapolis	346	100
Laodicea, Great Theatre	364	136
Limyra	195	not known.
Mantineia	227	not known.
Miletus	474	224
Myra	360	120
Nicopolis [in Epirus)	360	120
Orange (scena only remaining, 336 feet wide, 114 feet high).		
Patara	265	96
Perga		25 rows of seats.
Phellus	400	Scena 150
Pola, about (destroyed 1636, but plan preserved by Scamozzi)	200	68
Pompeii	190	62
Pompeiopolis	219	138
Rome, theatre Marcellus	517	172
Sardes	396	162
Selinus (in Cilicia)	114	
Sicyon	313	100
Side	390	120
Sparta	453	217
Stratonicea	390	106
Syracuse	440	
Tauromenium	330	width of scena 132
Teos	285	70
Tralles	540	150

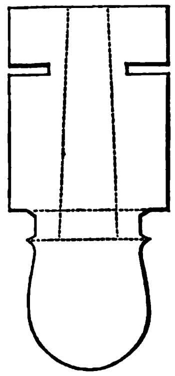
Of some of these theatres scarcely anything remains, little more than their general shape and extent being now distinguishable; accordingly the statements of their dimensions are not to be strictly relied upon, though they are sufficient to enable us to estimate their comparative size.

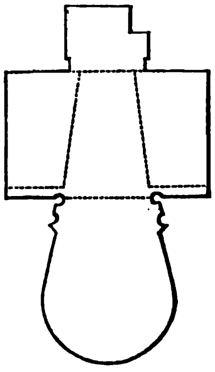
Fortunately the ancient theatre was not taken as a model for modern structures of the kind. The revival of theatrical representations took place before anything was known relative to that branch of archæology, and under very different circumstances. Dramatic entertainments were in the middle ages either partly religious, and performed within churches, convents, and colleges; or were acted for the amusement of princes and nobles on occasions of state and festivity, in halls merely temporarily fitted up for that purpose; consequently spacious and permanent structures, as public theatres, were not required until long afterwards, when the drama had become a distinct profession. In the meanwhile a taste for scenic display had developed itself, which required a very different arrangement of the stage and its apparatus from that of the ancients. Imperfect as they were in many respects, the dramatic pageants and recitations performed before Leo X. were "got up" with great magnificence, and some of the greatest artists were employed upon the decorations; among others Baldassare Peruzzi [PERUZZI, in BIOG. DIV.], whose skill in architecture and perspective carried scene-painting almost to perfection at once. Even in the preceding century dramatic exhibitions had been produced at Florence in a style then unprecedented; and we are told that the first Italian theatre was one erected in that city by Bernardo Buontalenti in 1581; but it does not appear to have been a public theatre, nor could it have been very spacious, as it now forms merely a saloon in the building called the Uffizi. Theatres on the present system were not built until the early part of the 17th century: just before which time an attempt had been made to restore the form of the ancient theatre and stage, with the permanent architectural scena and its entrances, by Palladio, whose celebrated Teatro Olimpico at Vicenza is one of those things which have gained a traditional reputation far beyond their real merits. Admired at first, because then superior to anything of the kind, it has continued to be admired since, partly on account of the character attached to it, which few care to dispute; and partly perhaps on account of its singularity, and because it shows the peculiarities of the ancient theatre. By no means, however, is it a very accurate imitation, though its chief merit lies in being a mere imitation; it is semi-elliptical instead of semicircular, with the stage on the longer axis of the ellipse; and on this account it looks too much squeezed up one way, and stretched out the other, and produces the same kind of disagreeable effect which would arise from placing the stage on the longer side of a parallelogram of the same extent (96 x 45 feet). It is said that the space to which the architect was restricted compelled him to adopt that form, yet it hardly appears so from the published plans of the building, for it would not be difficult to show how a semicircle might have been brought in. The scena, for which unlimited admiration is claimed, abounds in architectural barbarisms and solecisms. It is, however, the avenues seen beyond the scena through the centre arch and other openings which attract notice, and have been extolled by some as greatly superior to the "flimsy" painted decorations upon canvas used in modern theatres. Those avenues represent as many streets, the fronts of the buildings being modelled or carved in relief, and attempted to be shown in perspective by the floor and ceiling sloping very much upwards and downwards, and the other horizontal lines accordingly, and by the passages themselves being narrower at the further end. The contrivance is puerile at the best; and instead of being more deceptive or natural than painted scenery, the imitative perspective becomes distorted when viewed from any other situation than the centre of the theatre and the level of the stage. It is also difficult to understand how these narrow enclosed passages could have been properly lighted at the time of a performance; and although they are, in stage language, "practicable," they could hardly have been made use of, at least not for their whole extent, because at their further end an actor would appear gigantic. We are not aware of more than one other attempt to revive the ancient theatre in all its strictness, which was that built in 1588 at Sabbionetta, for the Duke Vespasiano Gonzaga, by Scamozzi, who completed the Teatro Olimpico after Palladio's death.

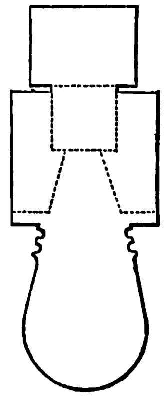
In claiming a decided superiority for the modern theatre over that of the ancients, we speak only as regards the respective systems; and as Ugoni, in his Life of Milizia, observes, to prefer the Grecian theatre, with all its inconveniences and the awkward expedients resorted to in it, as being of more classical and dignified character than our own comparatively small and fragile yet greatly improved structures of the kind, is to wish to limit art and science within their first bounds. There certainly was good reason at one time for exclaiming against modern theatrical architecture as very defective in regard to the audience portion of the "house." Till within a comparatively late period, scarcely any study was bestowed on beauty and convenience of plan. The accommodations were hardly so good as those in many very ordinary playhouses, where for want of space, there are no other seats than what directly face the stage. The "house" was usually an oblong, either rectangular or elliptical, so that the greater part of the audience,—at least those in the boxes,—were placed quite on the sides. Where the "house" contracted towards the proscenium, as was frequently the case, the side-boxes were actually turned *from* the stage; and whether such was the case or not, they were allowed to encroach upon the stage itself in such manner, that when the actors advanced to the front of the stage or beyond the line of the curtain, they may be said to have mingled with the audience, and those in the boxes on the *avant-scene* were actually behind them. If we may judge from the plans and other drawings of them, the two principal theatres in London were, even less than a century ago, both as inconvenient and as ugly as can well be imagined. The approaches, too, used formerly to be exceedingly bad; not only mean and inconvenient, but in many places most dangerously narrow. Such is strikingly the case in most of the modern Roman theatres, for instead of the box-corridors following the curve of the "house," and being of the same width throughout, they are so contracted where the other is widest, that more than two persons cannot pass.

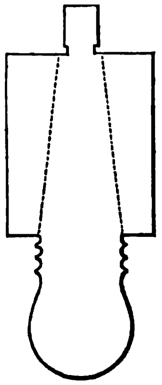
Very great reforms have now taken place, yet there is still room for further improvements, obvious, though not likely to be adopted so long as it is considered a matter of course that the space before the curtain must be made to contain as many persons as can possibly be packed into it, and that an audience must be piled up around the whole house to the very ceiling. We do not say that modern theatres are too lofty; the error does not lie there, but in carrying up the boxes, tier after tier, to such a preposterous height that the uppermost box is several feet above the top of the curtain or stage-openings, and the back seats of the upper gallery are actually on a level with the ceiling over the pit. Such accumulation of diminutive stories gives a crowded appearance to the whole, and leaves no space for architectural decoration around the upper part. No doubt a very striking appearance of a different kind presents itself from the pit and from the stage, when the house is entirely filled to the very top; and if we consider merely the *coup-d'œil* from such points, it may be allowed to be imposing. But then, as regards that part of the audience who occupy the upper part of the house, the arrangement is bad. From the seats which are at all above the level of the top of the curtain, there is only a bird's-eye view of the stage and the scenery, and that only from the front seats, and also facing the stage; for from those on the side of it it is impossible at that height to obtain a sight of the scene or even of the actors, unless when they come forward towards the foot-lights. There should be no seats at a greater height than that of the centre of the curtain, or the level of what is now the second tier of boxes in our large theatres; for, as the scenery can be painted only to one horizon,—generally that of the stage itself,—its perspective effect is more or less impaired when it is seen from either very much above or below that level. No less preposterous is the practice of continuing the side-boxes up to the proscenium, and sometimes (as in Her Majesty's Theatre at London) quite up to the very curtain, so that there is no proscenium at all, unless the space on the floor of the stage, between the curtain and foot-lights, can be so called. While those so seated lose the scenery altogether, they have the disadvantage of seeing between the wings on the side opposite them; and although the positive inconvenience resulting from such arrangement is felt only by a portion of the audience, the bad effect occasioned by it extends to the whole theatre. Not only ought there to be a distinct proscenium, serving as an architectural frame to the stage and its scenery, dividing that part of the theatre from the rest, but it ought to be of much ampler proportions than are now given it. It should extend so far as to leave some interval—a sort of neutral ground—between the curtain and the boxes, so as to remove the nearest spectator in them to a tolerable distance for properly viewing the stage as a picture; for it is possible to be as inconveniently near the stage as to be inconveniently distant from it. When, in order to contract the stage, or to render the pit and general diameter of the house considerably greater than what is required for the width of the curtain, the plan is made to approach a circle (as is the case in nearly every theatre built within the last forty years), the boxes should be confined to the semicircle facing the stage; and, so far from being a blank, the curved space on each side between them and the curtain might be made to contribute very much to the architectural appearance of the whole house. This would not take away anything from the pit; and if it materially diminished the number of the boxes and seats in them, it would be only where there ought to be nothing of the kind. The banishing of boxes from such situations, and making also no more than two tiers, would certainly greatly abridge the present capacities of theatres: a house of the same size would not contain the same number of persons as at present, when a large part of the audience are put where they cannot well see the performance. It is likely, therefore, to be objected that such a system would be too expensive, since a large house would be requisite for a


Munich.


Moscow.


San Carlo, Naples.


La Scala, Milan.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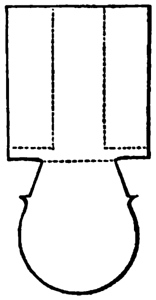
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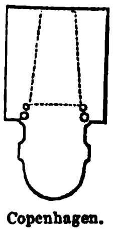
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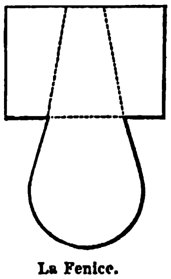
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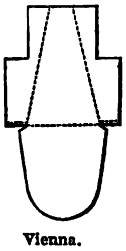
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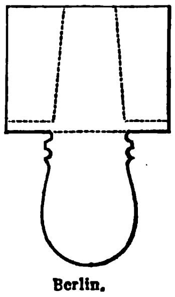
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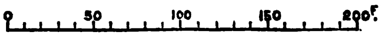


comparatively moderate audience; but curtailments might very well be made elsewhere, for at present the whole building is frequently much larger and more costly than actual necessity requires, the "house" itself, be its dimensions what they may, taking up a comparatively small area of the entire plan, while the rest is occupied by stately approaches and saloons, which, where economy rendered it expedient, might be greatly abridged, and much plainer in style, and some of them omitted altogether as superfluous appendages.

In some of the modern Continental theatres, plans of which are given on the previous page, the pomp displayed in the accessory parts of the building far exceeds anything of the kind in this country. In that at Berlin, besides several other spacious apartments, is a music-saloon 38 feet high, 44 wide, and 106 feet in length in its upper part, where there is a screen of six Ionic columns at each end; the whole highly decorated, and forming one of Schinkel's richest pieces of interior architecture. The theatre at Münich has two staircases to the boxes, with flights of marble steps 13 feet wide; and besides two saloons for the public (each 82 × 31 feet), there is a very magnificent one communicating with the royal box—not a mere ante-room, but what would be termed a noble room even in a palace, its dimensions being 46 × 44 feet, and 25 in height. In both these theatres, and in that of Genoa, the royal or state box is itself a room of some size, about 15 by 18 feet, more or less; and according to the general custom of the Continental theatres, this box (which occupies the height of two tiers, and is adorned with caryatides in front) is directly in the centre of the house, facing the stage, consequently in the very best situation of all; whereas the situation usually assigned to royal visitors in our theatres is almost the very worst, so far as seeing the stage and the performance is concerned.

In regard to the form of the "house," a decided improvement has taken place of late years; and the circular plan, or one approaching to it (either extended by the curtain being a tangent to the circle or somewhat beyond it, or reduced by the curtain intersecting and forming a chord to the segment), may now be considered the one established as being the most pleasing and commodious—that which is best adapted for affording a distinct view of the stage to the majority of the audience. But there is considerable difference of opinion as to its being the best form in regard to hearing. In fact, the science of acoustics is not yet thoroughly understood as regards practical purposes in building: it is easy enough to ascertain beforehand how much of the stage will be visible from different parts of the theatre, but not so what will be the result as to sound, since that will depend upon a variety of circumstances, some of them counteracting each other, and not every one of them to be guarded against or foreseen. The shape of the house is but one of these circumstances out of many: so much will also depend upon size, upon the depth of the boxes and galleries, and also upon accidental and such trivial matters, that any defect or advantage so occasioned is not likely to be traced to them. Here the chief guide is experience; and experience seems at present to be in favour of, at least not all against, the circular form; for the new theatres at Mainz, Dresden, and other places where it has been adopted, are said to be satisfactory in regard to the actors being distinctly heard in every part of the house.

While in their internal embellishment and fitting up theatres afford very great scope to the architect, though not so much as they might do, they also afford opportunity for accomplishing much in regard to characteristic external design. Magnificent as are the exteriors and façades of the theatres at St. Petersburg, Berlin, Munich, Bordeaux, and Nantes, with their poticoes and colonnades, there is nothing in them that very clearly expresses their particular purpose, because nothing that corresponds with, or indicates, the form of the "house" itself within. Moller, we believe, was the first who made the internal plan discover itself from without, by making the auditory—at least the corridors and saloon surrounding it—project out as a spacious semicircle, in the façade of the theatre at Mainz. The same form of exterior has been given by Semper to the new theatre at Dresden, which is also remarkable for the display it makes of sculpture. The new Covent Garden Theatre, it may be observed, is as deficient in character as any of the earlier structures of the same description mentioned above. Its internal arrangements are also of a very commonplace nature. The forthcoming competition for the new Opera of Paris may perhaps elicit some originality of treatment; but as modern habits interfere with the taste for theatrical amusements, it is to be feared that theatres themselves will hardly inspire any great art.

After all it is the stage, with its multifarious contrivances and complex mechanism, its scenery and pictorial effects, which manifest the extraordinary perfection to which the moderns have carried the scenic art. It does not enter into our purpose, however, to speak of stage mechanism, which is a subject and study by itself, and not otherwise connected with theatres and their architecture than as being made use of in the former. Those who seek for information of the kind will meet with many plates showing the stage construction and mechanism of Plymouth Theatre, in Foulstone's 'Public and Private Buildings, in Cavo's 'Architectonique des Theatres,' &c.; and, with more general and complete instructions, in Stephenson's work on the machinery of theatres. We will only observe that very great improvements and numerous contrivances for producing stage and scenic effects had been introduced into theatres at the commencement of the 17th century.

THEATRE. Before the reign of Elizabeth theatrical representations appear to have been subject to no legal restraint beyond the liability of those who conducted them to the vagrant laws.

But, although players, as such, were subject to no general legal restrictions, it is probable that the practice of granting licences from the crown to such persons prevailed as early as the reign of Henry VIII. The earliest theatrical licence from the crown now extant is that granted by Queen Elizabeth, in 1574, to James Burbage and four other persons, "servants to the Earl of Leicester," which contains a proviso that the performances thereby authorised, before they are publicly represented, shall be seen and allowed by the queen's master of the revels; a stipulation analogous to the licence of the lord chamberlain under the Licensing Act at the present day. These licences from the crown were originally nothing more than authorities to itinerate, which exempted strolling players from being molested by proceedings taken under the laws or proclamations against vagrants, and also superseded the necessity of licences from local magistrates.

Although theatrical representations became much more general in the reigns of James I. and Charles I., no laws were enacted for their regulation, with the exception of the stat. 1 Car. I. c. 1, which suppressed the performance of "interludes and common plays" upon the Lord's Day. An ordinance of the Long Parliament, in 1648, was directed to the suppression of all stage-plays and interludes, but though occasionally enforced with much rigour, it failed to abolish these entertainments. The stat. 12 Ann. stat. 2, c. 23, in general terms, classed players of interludes as rogues and vagabonds; but the stat. 10 Geo. II., c. 28, s. 1, expounded the former statute, by enacting that "every person, who should for hire, gain, or reward, act, represent, or perform any play or other entertainment of the stage, or any part therein, if he shall not have any legal settlement where the offence should be committed, without authority by patent from the king, or licence from the lord chamberlain, should be deemed a rogue and vagabond within the stat. 12 Ann." This provision is now repealed by the stat. 5 Geo. IV. c. 83, and players as such, whether stationary or itinerant, are, at the present day, not amenable to the law as rogues and vagabonds. By the 2nd section of the above statute, 10 Geo. II. c. 28, which, with the exceptions just mentioned, is still in full operation, and forms the law of the metropolitan theatres, it is enacted generally, that "every person who shall, without a patent or licence, act or perform any entertainment of the stage for hire, gain, or reward, shall forfeit the sum of 50*l*." By the 3rd section it is declared, that "no person shall for hire, gain, or reward act, perform, or represent any new interlude, tragedy, comedy, opera, play, farce, or other entertainment of the stage, or any parts therein; or any new act, scene, or other part added to any old interlude, tragedy, comedy, opera, play, farce, or other entertainment of the stage, or any new prologue or epilogue, unless a true copy thereof be sent to the lord chamberlain of the king's household for the time being, fourteen days at the least before the acting, representing, or performing thereof, together with an account of the play-house or place where the same shall be, and the time when the same is first intended to be first acted, represented, or performed, signed by the master or manager." The 4th section authorises the lord chamberlain to prohibit the performance of any theatrical entertainment, and subjects the persons infringing this prohibition to a penalty of 50*l*., and the forfeiture of their patent or licence. The 5th section provides that "no person shall be authorised by patent from the crown, or licence from the lord chamberlain, to act, represent, or perform for hire or reward, any interlude, tragedy, comedy, opera, play, farce, or other entertainment of the stage, in any part of Great Britain, except in the city of Westminster and within the liberties thereof, and in such places where the king shall personally reside, and during such residence only." The 7th section enacts, that "if any interlude, tragedy, comedy, opera, play, farce, or other entertainment of the stage, or any act, scene, or part thereof, shall be acted, represented, or performed in any house or place where wine, ale, beer, or other liquors shall be sold or retailed, the same shall be deemed to be acted, represented, and performed for gain, hire, and reward." Within a few years after the passing of this act of parliament, the clause which restricted the power of granting patents by the crown to theatres within the city of Westminster and places of royal residence, was found to be productive of inconvenience; and special acts of parliament were passed, which exempted several large towns, in which such entertainments were desired, from the operation of that clause, and authorised the king to grant letters for establishing theatres in such places.

A further relaxation of the rule established by the stat. 10 Geo. II. c. 28, for the regulation of theatrical performances, was effected by the statute 28 Geo. III. c. 30, in favour of places which could not be expected to bear the expense of a special act of parliament. By this latter statute, the justices of the peace at general or quarter sessions are authorised to license the performance of any such tragedies, comedies, interludes, operas, plays, or farces as are represented at the patent or licensed theatres in Westminster, or as have been submitted to the Lord Chamberlain, at any place within their jurisdiction not within 20 miles of London, Westminster, or Edinburgh, or eight miles of any patent or licensed theatre, or ten miles of the king's residence or fourteen miles of either of the universities of Oxford or Cambridge, or two miles of the outward limits of any place having peculiar jurisdiction.

The penalties imposed by the stat. 10 Geo. II. c. 28, being found in practice insufficient to prevent the performance of theatrical entertainments without licence, and great evils being alleged to follow from the resort of the lower orders in London to such entertainments, the legislature, in the year 1839, gave additional powers to the metropolitan police for their prevention. By the 46th section of the stat. 2 & 3 Vict. c. 47, "the commissioners of police are empowered to authorise a superintendent, with such constables as he may think necessary, to enter into any house or room, kept or used within the metropolitan police district for stage plays or dramatic entertainments, into which admission is obtained by payment of money, and which is not a licensed theatre, and to take into custody all persons who shall be found therein without lawful excuse." The same clause enacts that "every person keeping, using, or knowingly letting any house or other tenement for the purpose of being used as an unlicensed theatre, shall be liable to a penalty of 20*l.*, or, in the discretion of the magistrate, may be committed to the House of Correction, with or without hard labour, for two calendar months; and every person performing or being therein without lawful excuse shall be liable to a penalty of forty shillings."

THEBAINE. [OPIUM, ALKALOIDS OF.]

THEBET, in Hebrew מֵבֵת, is the fourth month of the civil year, and has twenty-nine days only. The name occurs in the Bible, at Esther ii. 16, where it is called the tenth month, in accordance with the ancient reckoning. It is a winter month, and will vary from December to January; the month Thebet of the year 5621 began on the 14th of December, 1860, and ended on the 11th of January, 1861. Josephus writes the name *Τέβεδος*, in the eleventh book of his Antiquities, ch. 5, § 4, where he speaks of the command of Ezra to the Jews to put away their strange wives, but Ezra in x. 9, places this in the 9th month, and Josephus himself makes it to correspond with *'Απελλαῖος*, so that we have a clerical error here. On a monument at Palmyra it is written as in Hebrew, but the Samaritan read Tebith, according to Scaliger. Benfey derives the name from some ancient Persian word, meaning "winter," which was probably Tapas, as in the cognate Sanskrit. A fast is observed on the 10th of the month in memory of the siege of Jerusalem by Nebuchadnezzar, as mentioned in ch. xxv., v. 1, of the second book of Kings. Another fast is mentioned, but not generally observed, to show the abhorrence of the Jews for the Septuagint version of the Bible; it is given to the 8th day of the month. Another fast is attributed to the 9th day, without any assigned reason; and a festival for the exclusion of the Sadducees from the Sanhedrim: but all these, except the first-mentioned, are rarely observed.

THEFT. [LAW, CRIMINAL.]

THEINE. [CAFFEINE.]

THEMIS (*Θέμις*), a Greek divinity, was, according to Hesiod and Apollodorus, a daughter of Uranus (Heaven) and Gaea (Earth), or, according to Tzetzes, a daughter of Helios. She was a favourite of Zeus, and bore him several daughters,—the Horæ, Eunomia, Dice, Eirene, and the Moerae. (Hesiod, 'Theog.,' 135, 901, &c.; Apollodorus, i. 3, 1.) These personified abstractions, which are represented as her daughters, show the ideas which the ancients had formed of her character, and consistently with these ideas she appears in Homer as a personification of the order of things sanctioned by usage or by law, and as the goddess who rules in the assemblies of the people. (Homer, 'Odyss.,' ii. 68, &c.) According to the same poet she lived with the other great gods in Olympus, was on good terms with Hera, and occasionally assembled the gods at the command of Zeus. (Homer, 'Iliad,' xv. 87, &c.; xx. 4, &c.) Diodorus (v. 67) states that she was believed to have made men acquainted with the will of the gods, the mode of their worship, and to have instituted laws, religious as well as civil. As a deity revealing the future she was believed to have been in possession of the Delphic oracle after her mother Gaea, and previous to the time that it came into the hands of Apollo, whence the act of giving an oracle was, even in later times, frequently called by a word derived from her name (*θεμιστεύειν*). She was worshipped as the goddess of law and order in various parts of Greece, as at Thebes, Olympia, Athens, Tanagra, and Troezen. She is frequently represented on coins in form resembling that of Athena, but carrying the horn of plenty in one hand and a pair of scales in the other.

THENARD'S BLUE. [COBALT.]

THEOBROMA. [CHOCOLATE AND COCOA.]

THEOBROMINE ($C_{14}H_8N_4O_4$). A vegetable alkaloid, homologous with caffeine, found in cocoa. It is obtained by extracting cocoa with boiling water, adding acetate of lead to the clear solution, filtering, removing the excess of acetate of lead from the filtrate, and then evaporating to dryness. The residue is to be treated with boiling alcohol, which deposits crystals of theobromine on cooling. These are to be purified by recrystallisation.

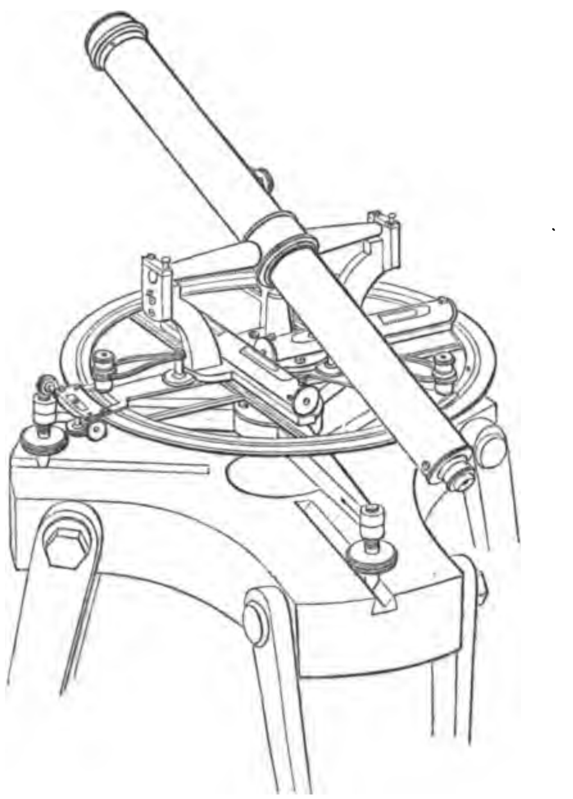
Theobromine is very slightly soluble in boiling water, and still less so in alcohol or ether. It possesses a slightly bitter taste, and can be sublimed without decomposition. It combines with acids, forming salts, which however possess little stability.

THEOCRACY (*θεοκρατία, a government by God*) is a term applied to the constitution of the Israelitish government, as established by Moses, on account of its being under the direct control of God. In fact, in the earliest form of the Israelitish constitution, *God was their king;* and the desire of the people to have a king at the time when Saul was raised to that office is expressly declared to be an act of rebellion on their part. (1 Sam., viii. 7.)

The theocracy did not supersede the establishment of a visible human government, consisting of judges and other officers, but all these officers were considered as subordinate to God as the only supreme ruler of the state.

THEODOLET, or THEODOLITE (the word is found in both forms), is the name generally given to the instrument used for measuring horizontal angles. In its simplest form the theodolet consists of a divided circle, which is to be set parallel with the horizon, and a telescope which has so much motion in a vertical plane as to enable the observer to view any object which he may require above or below the horizon. The derivation of the word is obscure, although the instrument and its name are comparatively of recent date. The earlier observers did indeed use divided circles, which they called *astrolabes*, *armillas*, &c. [ASTROLABE], for the purposes of surveying, but these were, generally speaking, very rude. The quadrant was employed in all accurate surveys up to the latter half of the last century, although Roemer had shown by reason and example the superiority of the entire circle. [CIRCLE.] The first instance of a survey conducted with an entire circle, on a considerable scale, was, so far as we recollect, the Survey of Zealand by Bugge, in 1762-8. (See Bugge's 'Observationes Astronomicæ,' p. 54, where he refers to a description of this instrument in Danish, and p. 61, where he states its merits.) The horizontal circle was two feet in diameter, and constructed by the Danish artist Ahl.

Ramsden finished his great theodolite in 1787, the circle of which is three feet in diameter. This was used for a triangulation, to connect the Observatories of Greenwich and Paris. A very full description of it is given in 'An Account of the Operations carried on for accomplishing a Trigonometrical Survey of England and Wales,' London, 1799, pp. 107-130, with four plates; a reprint, in a great measure, from the 'Phil. Trans.,' vol. 80 *et seq.* The principal triangles of the English, Irish, and Indian surveys have been observed with this instrument or with those nearly identical in size and construction; and though several minor additions and improvements have been made, the great theodolite is still considered as a very efficient and almost infallible instrument. We believe that the high reputation of the great theodolite depends in a great degree on the *superstitious* care with which it has been used and preserved: it is undoubtedly a very fine, well-divided instrument, but in common hands its want of solidity and firmness would probably have been felt. It would be impossible as well as useless to give an account of the various constructions of different



artists at home and abroad; but the reader who desires to see what had been done up to 1851 is referred to the Jury Report, Class X., where the surveying and levelling instruments and theodolites of the Great Exhibition are pretty fully noticed, as to their new points and from the personal observations of Mr. Glaisher. The general properties of a theodolite, that it should be firm, well balanced, &c., will be easily recognised by a person who knows how to make good use of the instrument, and we shall advert in the course of this article to some of the qualities which are, and to others which are not, essential.

We have given on the preceding page a sketch of the theodolite in its simplest form, such as would be proper for the secondary triangulation of a national survey, or for the most accurate private survey. The tripod which carries the instrument rests with three foot-screws in brass notches let into the top of a wooden stand. The legs of the stand are not fully represented, but the two parts of which each is composed end below in a strong and sharply-pointed metal socket. The circle is fixed, and the upper works, telescope, verniers, levels, &c., turn on a centre, which may be seen just under the cross of the telescope. The adjustments are very simple. The wooden stand is first set down with a good opening of the legs, and the top nearly horizontal. The foot-screws are placed in their notches, the plumb-line hung from its hook, below the centre of the circle, and the telescope turned round till one level is parallel to the line joining two foot-screws, while the other level is in a line from the third foot-screw to the centre. Bring the bubble of the first-mentioned level into the middle by raising one of the two foot-screws and depressing the other, and then adjust the cross-level by raising or depressing the third foot-screw alone. Now turn the telescope round 180°, and if the bubbles are not in the middle, bring them half way there by touching the foot-screws, and the other half by screws which adjust the levels themselves. When this has been nicely done, the bubbles will remain in the middle in every position of the telescope. If the objects to be observed lay all in the horizon, or in a plane parallel to it, the above adjustment would be sufficient; but when the objects are out of the horizontal plane they must be referred to it by a perpendicular, that is, the plane described by the telescope must be a great circle, and must also pass through the zenith. There are generally two wires at least in the focus of the telescope, one horizontal and the other vertical. Place the eye-piece to give sharp vision of the wires, and turn the milled screw, seen towards the object-glass, until the objects you are going to observe are distinct. Place the vertical wire on any well-defined object, making the bisection near the crossing of the wire; raise or depress the telescope until the object is nearly at the bottom or top of the field; if it is still bisected, the wire is rightly placed, but if not, twist the tube carrying the eye-piece so as to effect a bisection. To make the telescope describe a *great* circle, select some well-defined object near the horizon, and bisect it: now take the telescope *very carefully* out of its Y's, reverse it, and look again at the object. If it is still bisected, there is no error; but if not, the bisection is to be effected half by the tangent-screw of the instrument and half by the screws which carry the wire-plate, screwing up one and releasing the other. Restoring the telescope to its first position, it will be seen whether the adjustment is correct, and if not, the process must be repeated until the bisection is the same in both positions of the telescope, the clamp and tangent-screw remaining fixed. For the adjustment of the axis of the telescope a level would be convenient, but in this instrument the axis is supposed to have been correctly placed by the maker, and the only mode of correcting any error is by filing the Y's. It may be ascertained whether the axis is tolerably correct as follows:—Bisect an object as far above or below the horizon as the motion of the telescope will allow. Reverse the telescope, and if the object is still bisected, the pivots of the telescope are the same size: if not, the observer must deduce the difference of the pivots from the altitude and the error observed, which is not difficult. When this has been satisfactorily executed, bisect, as in the last instance, an object as far as possible from the horizon, and read off the verniers. Turn the instrument round 180°, return the telescope *end for end,* bisect the object again, and read off the verniers. If the mean readings differ exactly 180°, the axis is horizontal; but if they do not, the observer will have sufficient data from this, and the altitude or depression, for determining the quantity and direction of the error, which he may correct by the file or by calculation, according to his pleasure. There is a much easier method of examining the position of the axis by observing an object directly and as seen by reflexion from a fluid, as mercury, oil, or water. The axis is truly horizontal when the vertical wire bisects the object and its reflected image without moving the tangent-screw. It must be recollected that the adjustments of the horizontal circle already described must be previously and very scrupulously performed before attempting the examination or adjustment of the cross-axis.

As the objects in a survey are at very different distances, an adjustment is required for forming the image exactly on the wires. The use of the milled screw, seen towards the object-end of the telescope for this purpose, has already been mentioned.

In use, this theodolite should be placed on a repeating table or tripod, such as is to be found figured and described in Repeating Circle, and the repeating-tripod upon the stand. This was not done in the present plan for the sake of clearness. To adjust the repeating tripod, place the levels as described in the first adjustment, and clamp the theodolite. Bring the foot-screws of the theodolite over the foot-screws of the repeating-tripod by the motion of the tripod, and then by touching the foot-screws of the tripod or theodolite set the level-bubbles in the middle. Turn the upper plate of the tripod half-round, and again bring the bubbles into the middle, half by the tripod foot-screws, half by those of the instrument, and repeat the operation until the revolution of the repeating-table does not alter the position of the level-bubbles. The repeating-stand is now clamped, and the instrument itself is to be adjusted exactly as we have described above.

The course of observation after the instrument is adjusted is very simple. The problem is to measure the horizontal angle between two objects. Turn the telescope two or three times round in the direction in which you intend to observe, then bisect one of the objects, read off the verniers, and take a mean; bisect the second object, read the verniers, and take a mean. The difference between the two means is the angle required. This is all that can be done by the instrument as usually mounted; but with a repeating-table the operation is continued, thus:—Bring the telescope back on the first object, by the motion of the repeating-table, using its clamp and tangent-screw, and by the motion of the instrument bring the telescope on the second object. It is clear the motion of the repeating-table has merely restored the telescope to its original direction, without altering the readings of the circle; and that if the telescope be turned on the second object by its motion alone, without disturbing the circle, the difference between the mean of these new readings and the preceding mean will also be the angle required. By continuing the process, the angle may be measured as often as the observer pleases. It is evident that all readings-off, except the first and last, are superfluous, save as checks, or as giving the means of estimating the accuracy of the final result. The series should terminate after a whole number of revolutions as nearly as possible, when the excentricity of the repeating-table will be eliminated, a matter of possible importance if the objects are near and the repeating-table carelessly made, or, if the objects are pretty distant and this caution superfluous, when the verniers are nearly at the divisions at which you set out, which gets rid of or at least diminishes any errors of division. The latter condition is however rather a speculative than a practical one. As the error of division is divided by the number of observations, and the casual error of observation only by the square-root of the same number, it is evident that a moderate number of repetitions in our excellently-divided circles will reduce the error arising from mal-division to a much smaller quantity than that which belongs to the class of casual error of observation.

The essential condition of repetition is, that the motion of the theodolite shall not disturb the repeating-table. The motion of the latter therefore should be as heavy as will admit of nicety in the tangent-screw, while the motion of the parts which move with the telescope should be as light and free as is consistent with firmness. There is, we believe, no difficulty whatever in effecting both these points; but lest any error should arise from repetition, we should recommend a careful observer to determine his angles by two series,—one by always moving the telescope and its tangent-screw forward, and the repeating-stand and its screw backwards; and another, by reversing the process. If the two results agree, as they should do within the limits of casual observation, the mean is probably free from all other error; and if they do not, the observation should be repeated and varied until the quantity and probable law of the error is ascertained. We should then be able to say decidedly where, when, and under what precautions, repeating was a safe as well as a convenient and economical process, which at present is rather a *vexata quæstio,* unless the decision be supposed to be against all repetition, to which we do not bow.

The foregoing description has been confined to a form of theodolite which is not in ordinary use, though from its simplicity and power it is well adapted to the purpose of explanation. The common theodolite is generally carried by a pair of parallel plates, fixed on a three-legged staff. The lower of these circular plates is screwed upon the staff, and has an aperture above the screw. The upper plate has a strong descending shank which passes loosely through this aperture. A button of a spherical form is fixed on the end of the shank, the curvature uppermost, and rubs against the under surface of the lower plate, which is dome-shaped to fit it. Four strong screws pass through the upper plate and abut with their lower ends against the lower plate. When the screws are turned the plates are separated until the button and the spherical surface on which it rubs are brought into squeezing contact. To level the theodolite, set the levels each parallel to a diagonal pair of screws of the parallel plates. Then screw one pair until you come to a bearing, and by releasing one screw and screwing up the other, but not very tight, set the corresponding level horizontal; leaving this pair and taking hold of the other pair set the second level also right, and if the first level is deranged, as it probably will be a little, restore its position by screwing up the proper screw. Turn the telescope half round and correct the error, half by the parallel plate-screws, and the other half by the level-adjustments themselves. It is desirable that, when the final adjustment is made, the screws should bite pretty hard, otherwise there is a great chance that the upper plate will turn a little during the observation. This objection would seem fatal to the use of parallel plates where great nicety is required; they are however very convenient and of very ready use, and perhaps if the screws are strong and the observer is careful to give the telescope three or four turns round in the direction he means to observe, before starting, and always to move the telescope the same way, serious error may be avoided. The first object observed should always be observed at the end of the service, in order to see whether there has been any change in the original position. If one of the screws rest in a notch, perhaps the tendency to twist may be wholly overcome.

Another contrivance which is to be found in almost all theodolites is much more objectionable. The surveyor wishes to save himself addition or subtraction, and requires an adjustment by which he can turn the whole circle about and bring the telescope upon the first object, the verniers being previously set to zero. There is, therefore, a motion with a clamp and tangent-screw for this purpose, which, as the clamp has usually a very short bearing, is particularly liable to yield, and so to destroy all accuracy. To remedy this unnecessary evil, a second or *watch* telescope, as it is called, is attached to this part of the instrument, and brought to bear upon a well-defined object. Any motion or wriggling of the zero-clamp is betrayed by the watch-telescope, and when an angle is taken it must be first ascertained whether the watch-telescope keeps its position, and the position if disturbed must be restored to the zero-tangent screw, before the observation is finally made. In some theodolites made for the Indian survey, under the direction of Colonel Everest, the zero and slow-motion clamp take the form of a repeating-table, and may be so applied. It would be safer to have this motion made considerably heavier than in the patterns we have seen, and if the instrument is likely to fall into clumsy hands the watch-telescope might easily be added for greater caution. Such a theodolite would, so far as we can judge, have no limit to its accuracy, except that depending on the diminutive telescope.

For many purposes of surveying it is desirable that the telescope should allow of being considerably elevated or depressed, and that means should be given for measuring this angle with considerable accuracy. A circle, or portion of a circle, is then fixed upon the telescope axis, and the necessary verniers and level may be secured by a tail-piece or otherwise to the support. If the vertical angles are to be measured as accurately as the horizontal angles, the instrument becomes an altitude and azimuth circle. [CIRCLE.] But such instruments are rarely applied to the measurement of terrestrial angles. The direction of the meridian was determined in the Ordnance Survey by observing Polaris at its greatest elongations E. and W., and taking the middle of the two readings for the direction of the north. Hence, the telescope required all the transit adjustments except that for azimuth [TRANSIT], and was considerably elevated above the circle. Though the results were upon the whole satisfactory, yet we greatly doubt the prudence of ascertaining this fundamental and delicate point from such an instrument, or of risking the steadiness of the telescope supports by raising them so much above the body of the instrument. It would have been better, we conceive, to have determined the direction of the meridian by a series of careful transit observations, using more optical power with greater steadiness, and to have kept the theodolite to its proper office, that of measuring horizontal angles, greatly reducing the height of the telescope supports. The great theodolite had originally a semicircle fixed to the axis of the telescope, for measuring altitudes and depressions. This has since, very properly, been removed, and a whole circle substituted.

Where a theodolite is merely used for surveying, the telescope requires only a moderate vertical range. Mr. Troughton fixed a portion of a circle (which may be more properly called a *slice* than a sector) to one or two of his 12-inch theodolites, and this construction is often found in other makers. The telescope is thus kept lower, the instrument is firmer, and the larger radius gives the portion of the circle a seeming advantage over the entire circle of smaller radius. There is, however, something very unsatisfactory in a portion of a circle, and we should prefer a sort of compromise, giving the supports such an elevation as would allow a vertical circle of about half the dimensions of the horizontal circle. If the direction of the meridian is to be determined by this instrument, the supports must be at least so high as to see 2° or 3° above the latitude of the place, and the vertical circle may be increased accordingly.

It is perhaps requisite to give some description of the mode of adjusting the vertical circle. Where the supports are high enough to allow the telescope to pass when turned round in a vertical plane, all the adjustments are the same as in the altitude and azimuth circle. [CIRCLE.] When the telescope is too long for this, the circle must be lifted out of its Y's, in order to bring the line of sight again upon the object to be bisected, and then set down again. The operation is, in fact, the same, whatever be the nature of the vertical arch, and the adjustment is to be effected either by altering the level or the horizontal wire until the reading is the same in both positions of the telescope. If the observer has a Y level, or collimator, he can set the cross of his level-wires horizontal, and this being bisected by the telescope of the theodolite, the vernier must be made to read zero, and the bubble of the level be brought to the middle by its proper screws. Or if the observer possess two stands (and there is a great convenience in having more stands than one in surveying), he may place the stands at a considerable distance from each other, and, fixing the instrument on one stand, and a mark of exactly the same height as the telescope-axis on the other, observe the mark, noting its elevation or depression. Now, exchanging the instrument and mark, he must re-observe the depression or elevation exactly as before. On drawing the figure, it will be seen that if light move in a straight line, 90° − elevation at lower station = 90 − depression at higher station + the angle between perpendiculars to the earth's surface at each station, which last quantity is known from the distance between the stations, and may be easily calculated, that is, depression − elevation = a known angle. But if the zero is wrong, depressions will be increased while elevations are diminished, and *vice versâ*, so that depression observed − elevation observed − the known angle, instead of being = 0, will be ± 2 error of the vernier, which may be corrected accordingly either by the adjustment of the level or of the horizontal wire. Or, lastly, if the telescope has so much motion as that a star can be observed directly and by reflexion from mercury or any other fluid, the index-error of the vertical circle may be most accurately determined thus:—Take any star in the meridian, and having observed it directly, observe it immediately after by reflexion. If great nicety is required, the observations should be repeated alternately several times, and the partial results reduced to the meridian. The mean reading between the meridian altitude and meridian depression is the reading which corresponds to the horizon, and the difference of this from 0, or 90°, acording as the circle reads altitudes or zenith distances, is the error of the instrument, which may either be corrected or allowed for. This method, though very accurate, requires some knowledge of the time, and is rather restricted by the choice of stars. It is nearly as safe to observe a star not far from the east or west point, first directly, then by reflexion, and lastly, directly, making the contacts at following whole minutes, or at even or odd minutes if the interval of a minute is not sufficient. As the stars rise nearly uniformly in this part of the heavens, the mean of the first and third observations should give an altitude equal to the depression observed midway. The discrepancy between these results will be the double index-error as before, which may be corrected or allowed for. By some of these methods the index-error of the vertical circle or sector is to be found.

In some of the older theodolites the telescope rides in Y's at the top of the vertical arch, and is reversible as a level. The horizontal position of the telescope Y's can therefore be found as in any other level, and the verniers of the vertical circle set to zero when the telescope is horizontal. The vertical angles measured by these instruments are not, however, to be greatly depended on. They are usually greatly out of balance in all positions of the telescope, except the horizontal position, and therefore they make better levels than altitude instruments. This error may be partially got rid of by having a second level fixed to the instrument which is parallel to the plane of the vertical circle, and adjusted to the telescope-level when that is horizontal. If this supplementary level is pretty well graduated, it will show the tilt which is given the plane of the instrument by want of balance, and so give the correction required.

It may be as well to mention here that the principal adjustment being that of setting the plane of the theodolite horizontal, or, more correctly speaking, the principal axis vertical, any horizontal level anywhere placed is sufficient for the purpose, though the cross-levels are a little handier. A box-level is convenient, if a stand and repeating-table are used, to bring the planes nearly horizontal, and to make both ends of the bubbles visible at first.

Many surveyors give themselves and the instrument-maker a great deal of unnecessary trouble by being very difficult on the chapter of excentricity, which they confound with error of division. The English dividing-engines, up to the present time, do not divide the circles upon their centres; and therefore it frequently happens that the point round which the circle turns is not the point round which it is divided. When this error is not absolutely monstrous, the only effect is that one vernier gains what another loses, and that the mean of two opposite, or of three, four, or more equidistant readings, is precisely the same as if there were no excentricity. The advantage of a *little* excentricity is, that it gives you the benefit of an unbiassed reading at every vernier as well as the first: again, if all the verniers are recorded, it is a check on the dishonest observer, who might read one vernier and set down the rest. The instrument-maker must please his ignorant customer, and so either hammer his circle after it is divided, which may deform his work, or have an adjustment, which injures its solidity.

In Ramsden's great theodolite, and several others which have been made, the circle is read off by micrometer microscopes. Sometimes the microscopes revolve with the telescope (as the verniers do in our figure); sometimes the microscopes are fixed, and the circle revolves with the telescopes, as in Ramsden's theodolite.

Ertel of Münich has made several *astronomical* theodolites in which the rays entering into the telescope are reflected along the horizontal axis by a prism. The observer therefore looks in at the end of the horizontal axis, whatever the position of the star may be. The eye and body of the observer are more satisfactorily placed, and the supports are kept close and snug to the horizontal circle. The instrument is well adapted to one of its principal objects, observing stars at their passage over the prime vertical [TRANSIT]; but there is some trouble in finding an object when you have no better direction to look for it than your eye affords. Excellent latitudes have been determined by instruments of this class used in the prime vertical, and even the small vertical circle seems from some accounts to possess more power than from its dimensions we should have thought probable. As a general rule, the greater the number of readings, the less the effect of bad division, but beyond a limited number, the trouble and difficulty of reading-off is found in practice to counterbalance the advantage. Two opposite readings annul the effect of excentricity; three or four equidistant readings destroy such an error as would arise from the circles becoming elliptic after it was divided, or any error which follows the same law. In small stoutly-made theodolites we think two the most convenient number, and they can be much more conveniently read off than a larger number. When the circle is so much as 8 inches in diameter and the telescope good, we should prefer three or four readings. The vertical circle or sector may have two opposite readings. For many matters connected with surveying on the most extensive and accurate scale, see the memoirs published of the English, Scotch, and Irish Trigonometrical Survey; and the 'Base Métrique,' or account of the French measurement of an arc of the meridian, although that survey was conducted by a different instrument. Similar operations have been carried on in many countries during the last seventy or eighty years, and the memoirs which relate to these surveys contain the best information which can be had on the subject.

It should be mentioned that Mr. Simms has introduced a *Transit Theodolite*, or portable altitude and azimuth instrument, for the use of the scientific traveller and engineer. The ordinary vertical arc of the theodolite is extended to a complete circle, and is read by two opposite verniers. The range of the telescope is unlimited, and by means of a diagonal eye-piece observations can be made in the zenith. The axis is perforated for illumination of the field of view. The instrument is 8 inches in diameter.

THEODOSIAN CODE. In the year A.D. 429 Theodosius II. appointed a commission of eight persons, at the head of whom was Antiochus, to form a code out of all the constitutions and other laws which had been promulgated since the time of Constantine the Great. The code was to be formed on the model of the private compilations respectively called the Codex Gregorianus and the Codex Hermogenianus. Either nothing was done by this commission, or, for some reason, a renewal of it was thought necessary, and this renewed commission received its instructions in the year 435. This second commission consisted of sixteen members, with the same Antiochus at its head. In remodelling their materials the commission was empowered to omit the superfluous, insert the necessary, change the ambiguous, and reconcile the incongruous.

The code was completed and promulgated as law in the Eastern empire in the year 438; and it was declared that the laws enacted since the time of Constantine should only be in force so far as they were incorporated into this code. The code was forwarded in the year 438 by Theodosius to his son-in-law Valentinian III., who confirmed it and laid it before the Roman senate, by whom it was received. In the year 448 Theodosius forwarded to Valentinian other constitutions which he had made since the completion of the code, as circumstances had arisen; and these new constitutions were promulgated in the Western empire in the same year. The new constitutions were called Novellae, and all such new constitutions which were interchanged between the East and West, and had reference to the code of Theodosius, were called by the name Novellae. This interchange subsisted as long as the empire of the West continued: the last constitution of the kind that we know is one of Anthemius, who was contemporary with Leo I. in the Eastern empire: it belongs to the year 468, and relates to Bona Vacantia.

This code consists of sixteen books, which are divided into titles, and the titles are subdivided into sections. The arrangement of the matter differs from that in the subsequent compilation of Justinian, also called the Code. The code of Theodosius treats of Jus Privatum in the first part, and especially in the second and fourth books, both included, and in the beginning of the fifth: the following books treat chiefly of Jus Publicum. The first book treats of offices, and the sixteenth book treats of matters pertaining to the Christian church. The code of Theodosius was the first great compilation of the kind, and it was much used in the compilation of the code of Justinian. It also forms the basis of the code of the Ostrogoths, called the Edictum Theoderici; it was incorporated into the code of Alaric II., commonly called the Breviarium, in an abridged form, accompanied by a continual interpretation or explanation; and it was used in the compilation of the Lex Romana of the Burgundians, which is often incorrectly called Papiani Liber Responsorum.

The greater part of the Theodosian code and of the Novellae Constitutiones exist in their genuine state: the first five books of the code and the beginning of the sixth are chiefly found only in the Breviarium. The excellent edition of J. Gothofredus (6 vols. fol., Lyon, 1665, re-edited by J. D. Ritter, fol., Leipzig, 1736-1745), and also the edition of the Jus Civile Antejustinianeum, Berlin, 1815, have followed the text of the Breviarium for the first five books and the beginning of the sixth. But Clossius and Peyron have subsequently made additions to the first five books, and particularly to the first; the former from a Milan MS. of the Breviarium, and the latter from a Turin palimpsest of the Theodosian Code. ('Theodos. Cod. Genuina Fragmenta,' &c., W. F. Clossius, Tüb., 1824, 8vo.; 'Cod. Theodos. Fragment. inedd.,' &c., Amad. Peyron, 1823, 4to.) Hänel has also added to the later books.

THEOLOGY (*θεολογία*), the science which relates to God.

1. *Definition of Terms.*—All that men know of the nature of God considered absolutely, of the relations between God on the one hand and themselves and other beings on the other, together with the consequences resulting from those relations, and the duties arising out of those relations:—all this knowledge is described by the word *religion*. [RELIGION.] To reduce this knowledge to a systematic form, is the province of the science of *theology;* and the truths of religion, when arranged in a scientific form, constitute *a system of theology.* Theology stands to religion in the same relation as that in which every other science stands to its subject; for instance, natural philosophy to matter, metaphysics to the mind, philology to language. By many writers the words *theology* and *religion* are used as synonymous terms; but such a usage of them is incorrect.

The above definition applies to the word as it has been understood for some centuries; but its earlier use was somewhat different from this. The *θεολογία* of the ancient Greeks was *φιλοσοφία περὶ τῶν θείων*, the philosophy of divine existences; and it included all questions relating to the origin, the nature, and the service of the gods. As relating to the origin and mode of existence of the gods, Aristotle uses the verb *θεολογέω* ('Metaphys.,' i. 3); and Cicero the noun *theologus* ('De Nat. Deor.,' iii. 21). In a wider signification the word is used by Varro (Augustin., 'De Civitat. Dei,' vi. 5; compare Eusebius, 'Præparat. Evang.,' iv., 130), who distinguishes three different kinds of theology: (1) *μυθικόν*, or *fabulosum*, mythical or legendary; (2) *φυσικόν*, or *naturale*, physical, or relating to the nature of the gods; (3) *πολιτικόν*, or *civile*, political or popular. Of these, the first is the theology of poets, the second that of philosophers, the third that of the people.

In the New Testament the word is not used. (The title of the Apocalypse, in which the word *θεόλογος* is applied to the author, is much later than the book itself.) [APOCALYPSE.] The simpler terms *knowledge* (*γνῶσις*) and *faith* (*πίστις*) are those which approach most nearly to the meaning of the word *theology;* but the fact being that theology, as a system, is not taught in the New Testament, there is nothing surprising in the absence of the word.

Lastly, the modern usage of the word, as expressed in the above definition, was first adopted by Peter Abailard (ob. 1142), who drew up a system of scholastic divinity, to which he gave the title of 'Theologia Christiana.' It should be remarked that instead of the Greek word *theology*, the Latin word *divinity* is often used to describe the science of religion.

2. *Divisions of the Science.*—With reference to its foundation, theology is divided, as explained in the preceding paragraph, into *Natural* and *Revealed*, or *positive*. The latter word is used to indicate that the foundations of revealed theology are the *expressed will* of God; just as we speak of positive laws. The term *positive theology* is also used to describe any system of theology which rests upon authority, as, for example, the system embodied in the formularies of a particular church.

According to the method of treating the subject, theology is divided into *popular* or *biblical*, and *systematic* or *scholastic* theology.

According to the part of the subject which is treated of, it is divided into *theoretical* and *practical* theology. Of these, the former includes—(1) the knowledge of the documents which contain the revelation, the proof of their authority, and the explanation of their meaning, that is, *Exegetical Theology;* (2) the investigation, arrangement, and discussion of the truths so revealed, that is, *Systematic Theology;* (3) the workings and changes of religion among those who have professed it, or *Historical Theology*. *Practical Theology* has for its subjects the duties of practical religion, and the various modes of enforcing them on men; and with reference to the latter, it is divided into—(1) *Homiletics*, or preaching; (2) *Catechetics*, or teaching; (3) *Liturgics*, or worship and the administration of the sacraments; and (4) *Pastoral Theology*, or the care and government of a church.

3. *Dogmatic Theology*, or *Dogmatics*, means more than the term *systematic theology*. The province of the latter is simply to give to the scattered truths of revelation the scientific form of a connected system, in whatever manner may seem most convenient to the framer of the system; but *dogmatic theology* aims at forming a system which shall be accepted as binding by a large body of religionists, and then views all religious truth in the light of that system. It is *systematic theology*, with the idea of *authority* superadded.

Out of *Dogmatic Theology* springs *Controversial Theology*, or that mode of treating the subject of religion in which some particular system of dogmatics is defended, or some other system attacked.

See, further, the articles CANON; MIRACLE; RATIONALISM; and REVELATION; in which many of the subjects of dogmatic controversy are discussed.

THEORBO, a musical instrument of the lute kind, which has long fallen into disuse. This instrument has been called the *Cithara Bijuga*, its two heads having been erroneously considered as two necks; and it was commonly known under the name of Arch-lute, on account of its magnitude. The upper and middle strings were attached to the lower head or nut; the lower, or base strings, to an upper or additional one. According to *Maister Mace* (1676), the Theorbo was the old English lute very much enlarged, and used chiefly, if not only, as an accompaniment to the voice.

THEOREM (θεώρημα) means properly a thing to be looked at or seen; and is used in mathematics to signify any proposition which states its conclusion or makes any affirmation or negation; as distinguished from a PROBLEM, which demands or requires a conclusion to be arrived at, without so much as stating whether that conclusion is even possible. Thus: "Required to draw a tangent to a circle at a given point," is a problem; but "If a straight line be drawn at right angles to a diameter from its extremity, that straight line is a tangent to the circle," is a theorem. The problem asks discovery both of method and demonstration; the theorem asks demonstration only.

This distinction, as noticed in detail in PROBLEM, was not made by the older Greek geometers. Theodosius is the first, so far as we know, who uses the word theorem, but none of his propositions are problems. Pappus is the first who uses both terms in the distinctive sense.

THEORY, THEORY AND PRACTICE. If articles upon the mere meaning of words be admissible, it is the consequence of the manner in which the words are used. Of all the fallacies which infest society, the most common is that of applying to one sense of a word ideas or associations derived from another; and of all the words in use, there are few which are more often subjected to such process than those which stand at the head of this article.

By theory, properly speaking, is meant the mode of making seen and known the dependence of truths upon one another: a theory is a connected body of such truths belonging to one or more common principles. The use of this word has enlarged with the boundaries of the sciences. For example, before the discovery of universal gravitation, all that was known of any one planet was the empirical formulæ for one or two of its inequalities. This constituted the theory of the planet (then so called): thus the theory of the moon, so far as peculiar, consisted in the statement of the laws of the inequalities called the equation of the centre, the evection, &c. In our day the point of view is changed; it is no longer the mere exhibition of these inequalities which constitutes the theory, but the deduction of them, as necessary consequences, from the principle of gravitation. The theoretical astronomer now starts from this principle, and, taking only one position and velocity for his numerical data, finds out every inequality of the planetary motions, those which were previously known from observation and more, and shows how to form them into tables. The practical astronomer makes these tables, computes places from them for the current year, compares these places with the results of observation, and returning the comparison into the hands of the theorist, enables him, if need be, to correct the original numerical data to which he applied his methods, or to detect new inequalities. The process is now deductive; but before the time of Newton it was the other way. The observer had the first task; the inequalities were to be collected from comparison of observations, and their laws, reduced to the simplest form, were the data for future tables.

Again, before the introduction of the undulatory hypothesis, the theory of light consisted in the exhibition of the laws of reflexion and refraction, with a certain extent of explanation from the emanatory hypothesis of Newton. Since that time the theory of light has become, though at a distance, a resemblance of the theory of gravitation in its character: prediction has commenced, that is to say, the phenomena which would appear under certain new circumstances have been announced before any experiments were made to discover them; and correctly announced. This is the end to which theory ought to be constantly tending; namely, the discovery of laws of action in so complete a manner that the necessary consequences of those laws never fail to make their appearance, so that everything which is seen is found to be a consequence of the laws when examined, and every consequence of the laws is seen in phenomena when looked for. Whatever fulfils these conditions may be called a perfect theory, or a perfect *mathematical* theory.

The next step in the chain of discovery is one which may in most cases be incapable of attainment. For example, nothing is more certain than that the assumption of every particle of matter attracting every other particle, according to the Newtonian law, leads to the complete deduction of the celestial motions, and gives the complete power of prediction just alluded to. But whether this ATTRACTION does actually take place, or whether any intermediate agent is employed, though it matters nothing *at present* to the mathematical theory, is the next object of inquiry. Could this point be ascertained, it is more than probable that the knowledge of the constitution of matter to which it would lead, would open hundreds of important consequences even in the application of science to the arts. [CAUSE; HYPOTHESIS.]

Before coming to the distinction between theory and practice, we must observe that theories may be divided into two classes, the more perfect and the less perfect. We cannot say that any theory is absolutely perfect; but there are some of which the defects are hardly perceptible, and others in which the contrary is the case. For example, the theory of the statics and dynamics of *rigid* bodies is tolerably perfect; but that of bodies composed of particles acted on by molecular forces is in its infancy. We know a great deal more of the connection of the planetary worlds with each other than we do of the particles which, when connected together, form a bar of iron or of oak. We know that the bar is not perfectly rigid; that it bends and breaks: and the degree of bending which a given force will cause, and the amount of pressure necessary to produce fracture, must be sought for in experiments, from which, imperfect as they are, the laws which would follow from a good theory, if we had one, are to be deduced. In such a subject our theory, instead of being an all-sufficient *guide*, is only a *help*, the services of which are to be used to an extent which discrimination derived from practice and experience must point out. Many a person who thinks he is proceeding upon experience only is really making use of a mixture in which there is theory, though his own knowledge of the process he uses, and of its history, may not be sufficient to inform him of it.

A person who uses an imperfect theory with the confidence due only to a perfect one will naturally fall into abundance of mistakes; his predictions will be crossed by disturbing circumstances of which his theory is not able to take account, and his credit will be lowered by the failure. And inasmuch as more theories are imperfect than are perfect, and of those who attend to anything, those who acquire very sound habits of judging are few compared with those who do not get so far, it must have happened, as it has happened, that a great quantity of mistake has been made by those who do not understand the true use of an *imperfect* theory. Hence much discredit has been brought upon theory in general; and the schism of theoretical and practical men has arisen. Fortunately there are many of the former who attend properly to the improvement of imperfect theory by practice; and many calling themselves practical who seize with avidity all that theory can do for them, and who know that step by step theory has been making her way with giant strides into the territory of practice for the last century and a half.

By practice, as distinguished from theory, is meant (not by us, but by those who contend for the distinction) the application of that knowledge which comes from experience only, and is not sufficiently connected with any general principles to be entitled to the name of a theory. The distinction of labourers in the field of science or art into theoretical and practical is not strictly a just one, for there is no theorist whose knowledge is all theory, and there is no practical man whose skill is all derived from experience. But the terms will do well enough to distinguish two classes whose peculiarities it might be difficult to define exactly.

The practical man, when he is really nothing more, is one who can just do what he has been taught to do, and who has acquired skill and judgment in a small range of occupations. All who pride themselves upon the title would be displeased at this definition, and we readily admit that many of them are entitled to a higher character; but only because the title by which they delight to describe themselves is a wrong one. They desire, under the name of a workman, to claim the qualities of a master. The term *theoretical* serves, as one of contempt, to designate any thing of which they disapprove; and as there never is any fallacy which is not carried to a fool's-cap extent by the lower order of users, it would not be difficult to make a most amusing selection of instances of the manner in which the distinction has been worked by the large number who are at the bottom of the class, and in whose heads it runs that their own *ignorance* is practical and others' *knowledge* theoretical. Our attention was called to this class in early youth by hearing an educated person state that he was a "practical man," by way of declining a question which involved knowledge of *fractions*; it was then extracted from him, to the delight of bystanders, that all above *integers* is *theory*. And from that time whenever we wish, in a delicate way, to find out how much a person knows of his subject, we manage to ascertain to what extent he considers it *practically useful*. And we have thus discovered that what happens to ourselves happens to others, namely, that all knowledge which *is* possessed is practically useful, and all which *is not* possessed is not. It is very often noticed that men are unduly given to puff and vaunt their own professions; whereby they provoke the retort of "nothing like leather," being the words the currier used when he was asked what the city walls should be made of. The sarcasm is often unjust. The exaggerator is frequently giving a true account of the effects of *knowledge*: his mistake lies only in restricting those effects to the knowledge of things in his own line, the only knowledge he has ever sufficiently cultivated.

We say nothing about those to whom *theory* is but a name under which they may safely sneer at *knowledge*, except this: two small commercial companies sometimes prolong their existence by amalgamating, as they call it; would it not be desirable that they should join those who use the word *infidelity* instead of *theory*? We give a passing word to the many who blind themselves to the difference between truth and falsehood by disguising the latter under the name of practice. It chanced to us long ago to advise a very worthy man of business, now dead, upon the terms of an advertisement. On one of our alterations he remarked "Don't you think that, practically, it would read better my way?"—"It would," said we, "the objection is, that it would not be true." Our friend stared as if a light had broken in upon him, and said, "Well, Sir, there *is* something in that." We remember seeing a theorist, as he was called, endeavour to make the managers of a certain undertaking comprehend that their profits could not exceed the excess of the gross returns over the outlay, after they had been trying to *cheat the equation* by inventing names for what they would have liked to have, but which the theorist assured them they would not get, for the preceding reason. The answer was, "That is very true *theoretically*, but now let us look at it *practically*." We shall say no more of the gross abuse of the terms, except to remark that were it worth while really to make a contest between theory and practice, it would be difficult to say on which side the balance of absurdity would incline; or whether the man who is too confident in his theory, or too confident in his experience, has done most mischief for the time being.

Coming now to the higher class of practical men, and speaking as of the balance between two methods the value of both of which is admitted, we observe there are obvious faults to which both parties are subject, both in conduct, and in argument respecting their pursuits. Great care is necessary to secure the theorist from pushing an imperfect theory too far, and neglecting causes of disturbance; but at least as much is necessary to prevent the practical man from generalising into theory from imperfect experience, or from restraining inquiry by a notion formed from practice. This is his besetting sin, to such an extent that we should almost be inclined to say that the fault of a practical man is a tendency to form false theory, as that of the theorist is to make false applications. We have often been surprised at the boldness with which the former assert generalities, upon evidence which would only make a pure theorist look for further information. Analogies are of all things the most deceptive. Much and frequent attention to men's arguments has left us with a feeling which, whenever we hear a person begin with "I am a practical man," makes us say to ourselves, "Now for a smack of false theory."

In argument there is one mode which is common to both parties, and which is exceedingly detrimental. It is the selection of instances from the very highest minds of the two orders, to illustrate the effects of theory or practice upon the general mass of understandings: minds the superior calibre of which, and their power of adapting themselves to circumstances, and making the most of what they have, render them exceptions to all rules, and no proper examples of the most advantageous course of training. Every one likes, no doubt, to draw consequences about and concerning his own self from a contemplation of the minds and methods of the Newtons or the Galileos of a higher sphere of intellectual existence, or the Arkwrights or Telfords of a better state of power of adaptation. "What is your theory good for?" says the tongue attached to some head which holds about the same weight of conceit that Telford's did of sagacity; "Telford knew nothing of it, and I may do without it too." The answer is—*Telford*. The opinion of Bacon was, that "the root of *all the mischief* in the sciences is, that, falsely magnifying and admiring the powers of the mind, we seek not its real helps," a maxim full of meaning, and a lesson to him who rates theory too highly, and also to one who thinks that the only use of his mind is to arrange the results of experience, his own or others. What are the majority of men, that they should look down upon any course of training, theoretical or practical?

Another fault of argument, but almost peculiar to the practical world, who have the force of numbers on their own side, is the habit of claiming all who are successful in application as instances of their own method and knights of their own order. Suppose that one individual should discover a mine, work it with his own hand, purify the ore, and beat the metal into a horse-shoe; which is he, a geologist, miner, furnace-man, or blacksmith? He has done the work of all, but the community of blacksmiths would hardly be allowed to claim him as peculiarly belonging to themselves. When a person who has mastered the difficulties of theory has also successfully applied them, he is free of both corporations; but those who attend only to application, never fail to appropriate his merits. WATT is a striking instance; he was a highly accomplished theorist on every point on which he worked: and yet his name has been frequently cited as a proof that theory could be dispensed with. And his career, when compared with that of Telford, will illustrate theory applied to practice, as distinguished from practice alone, however acute. It is impossible to contemplate the career of Telford without a feeling of high interest, created by the comparison of his apparently inadequate education with his startling successes. Looking at the individual himself, there is everything for his age to admire; and so long as his structures last, each of them is the *monumentum*, but not *ære perennius*. The time will come when his name shall be like that of the builder of the old London bridge, who was no doubt the Telford of the day, a stimulus to his contemporaries, useful and honoured, but not the remembered of succeeding ages. On the other hand, the discoveries of Watt, though equally startling in what is called the practical point of view, have the mind of the discoverer impressed upon them, and have been, and must be, the guide of his successors, not merely to repetitions of what he did himself, but to enlargement of ideas, and to the conversion of principles into forms useful in art. Take away the honourable qualities which enabled the two men to outstrip their contemporaries, each in his line, qualities which are the properties of the individual minds, and consider what is left, namely, their modes of proceeding: consider the effect of these two modes upon men in general, and there is nothing in that of Telford which would raise the workman above a workman, while in that of Watt there is the vital principle to which we owe all the mechanical triumphs of civilisation and all the theoretical successes of physical philosophy.

This country has been long and happily distinguished for the great attention which has been paid to application; but it is a mistake to suppose, as some do, that our supremacy in practical matters has been co-ordinate with, still less owing to, neglect of theory. It would be easy to show that though the comparative neglect of theory alone, *as a pursuit*, added to its diligent cultivation on the Continent, under the encouragement of government, had given to foreign countries a decided preponderance, now very much on the wane, of theoretical inquirers and writers, yet that there has been no country in Europe in which a competent knowledge of the mathematics and their applications has been spread over so large a mass, or raised to so high an average. At any time since the beginning of the 17th century the total amount of theory in Britain has been larger than in any other European country, on account of the numbers who have possessed a useful amount of knowledge: the diffusion of education in Germany may have altered our position, but of this we are not sure. For ourselves we are perfectly satisfied, however little those most concerned may know it, that this greater diffusion of theory has been the original moving cause of the practical excellence to which we have alluded. If those who have become known for splendid achievements in the former are few, the same may also be said of the latter; but a country owes its excellence in either department, not to one or two of the highest, but to the mass of those who have competent knowledge, producing good habits of thought and action. It is a new thing to hear one branch set against the other, and would make our writers of a century back think that posterity had lost its senses. The only addition wanted has been some means of systematically nurturing the growth of theory, so that, well as we have done with what we have, we may do better with more. The efforts which are making on every side to extend education will, it may be hoped, do what is wanted in this particular; they will at least have the effect of making it clear that, whatever the force of genius may do for an isolated exception, the mass of mankind must place their best hope of progress in the union of theory and practice.

There is also a mode of viewing what we may call the action of theory, which is absolutely necessary to a true conception of the value of their labours who employ their time in its advancement. Watch the arguments of a person who calls himself, distinctively, a practical man, and it will be always found that a well-established theory, fifty years old, is practical knowledge, so called. To this there cannot be the slightest objection in the non-distinctive sense: a well-established theory, which has been shown to be sufficient, is highly practical, as opposed to one of which the investigation is more recent, and the completeness not so well ascertained. But when the question is theory, as theory, against practice, as practice, the advocates of the latter frequently find it convenient to assume, for their own share of the matters in contest, all the best theories *plus* the most recent practical knowledge, leaving to the other side the onus of supporting theory upon the most imperfect part of the mass of doctrines which it contains, being that part which is not yet off the anvil. Suppose a merchant going into the bail court to prove his being worth a certain sum: he is asked whether his business, all debts and risks allowed for, would produce that sum: he replies, that his ventures must be beyond record unsuccessful, if it would not be so, over and over again. "So then," he is further questioned, "you cannot positively swear that your business will make you worth the sum in question." "I cannot," he replies, "positively swear any such thing; but I have enough not employed in business, in land and mortgages, and in the funds, to pay twenty shillings in the pound five times over upon every risk which I am liable to." What would be thought of counsel who should retort, "That is nothing to us; you are described as a merchant, and your solvency must be tried by the state of that part of your property which is now undergoing the fluctuations of trade?" Such is and always must be the state of theory; the amount which is actually realised is enormously greater than the floating balance which is being worked out. Those who are engaged in producing fixed capital from the latter, have a right to the credit which arises from the interest of the former: their labours for the time being are not to produce their return at the instant.

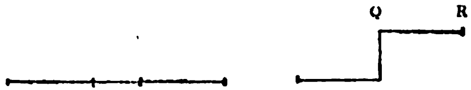
We have, in compliance with common notions, not adverted to the consequences of theory upon the mind and thoughts of men, but have treated it as if its sole object were to advance the mechanical arts and better the physical condition of society. But this is under protest that even if it could not be proved that rational investigation of nature had added one single atom to the physical comfort of life, there would remain such an enormous mass of social ameliorations which can be traced to that source as would outweigh even the triumphs of steam. This is often forgotten by the highest men of the highest and most valuable practice, meaning the best application of the truest theory. They confound practice with application to *matter* as opposed to *mind*. On this point we quote something we have printed elsewhere. "There is a strong impression in the world of physical inquiry that a mathematician is almost bound, whatever his pursuit may be, to make his science the means of investigating or registering some facts connected with the material world. A *teacher* of mathematics for example, whose business it is to study the mind and its discipline, that he may make his teaching permanently useful to those who will not, in nineteen cases out of twenty, ever have any need to apply it professionally, would be thought quite in the right way if he should take to investigating the force of steam, or the strength of beams, or the orbits of binary stars: they would call him a *practical man.* I should give him quite another name if he took up steam or star for anything beyond relaxation, supposing his taste to turn that way. The disposition to hold material application to be *always* practical is one of the consequences of the want of psychological thought, and will vanish before sound logical training, with other myopisms." ('Cambr. Phil. Trans.,' vol. x. p. 1.)

In conclusion, the word practice as opposed to *theory* takes an advantage from its meaning as opposed to *profession*. There are many persons who have so hazy a view of the two meanings as to imagine that the two antitheses are one and the same.

THEORY OF COUPLES. The two motions of which any rigid system is susceptible are those of TRANSLATION and of ROTATION. Each of these has this peculiarity, namely, that one particular case of its application yields the other kind of motion. Every motion of a system can, for any one instant, be resolved, at most, into a motion of translation of the whole system, combined with a motion of rotation about an axis; and every application of a system of forces to any rigid body, produces, generally speaking, this compound of translation and rotation. Also, if equal and opposite forces, such as would produce simple translation, be applied at the same point, or if equal and opposite forces, such as would produce rotation, be applied about the same axis, the result is that the equilibrium, or previous motion, of the system remains undisturbed.

But if the equal and opposite forces of translation be applied at different points, the result is rotation only, for the first instant; and if the equal and opposite forces of rotation be applied about axes not coinciding, but only parallel, the effect, at the first instant, is translation only. And though the doctrine of motion is now properly excluded from statics, yet the preceding theorems, together with others mentioned in ROTATION, should be well understood, and viewed in connection with the science of equilibrium, which is always illustrated, though it may not be demonstrated, by such considerations.

It was for a long time a curious but barren exception, that though any two forces acting in the same plane may, generally speaking, have their joint effect supplied by one single third force, yet if the two forces be equal in magnitude, and opposite in direction, no such single third force will do. If indeed they be applied in the same line, as O P and Q R in the first figure, they equilibrate each other; but if not in the same line, as O P and Q R in the second figure, no one single force can be found which will either equilibrate them, or produce their effect. Some years ago, M. Poinsot, already mentioned for his beautiful theory of ROTATION, applied a remarkable theorem connected with such pairs of forces to the establishment of the theory of the statics of rigid bodies, in a manner which has made his system rapidly take its place among the fundamental bases of the science. We shall in this article point out the manner in which this can be done, without much demonstration, with a view to draw the attention of those who have learned the doctrine of equilibrium in the old way: we cannot make it intelligible (without too great length) except to those who have learned the principles of analytical statics.

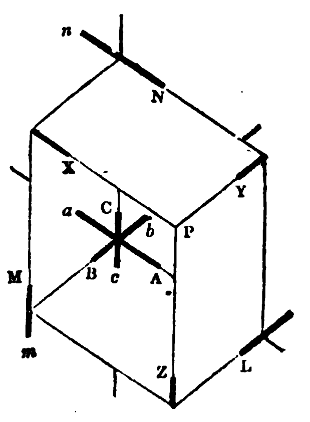


M. Poinsot called a pair of equal and opposite forces, not equilibrating each other, by the name of a *couple*—too general a term perhaps: by it is to be understood a couple which cannot be made anything but a couple, or cannot be replaced by one force: an *incomposible* couple. The *plane* of the couple is the plane drawn through the parallel forces; the *arm* of the couple is any line drawn perpendicular to the forces from the direction of one to that of the other; the *axis* of the couple is any straight line perpendicular to its plane. And if we consider any axis, it will be apparent that the moment or leverage of the couple [LEVER] to turn the system about that axis is represented by the product of one of the forces and the arm. For if, with reference to the axis, x be the arm of one of the forces, $x \pm a$ is that of the other, a being the arm of the couple. Hence if P be one of the forces, the united leverage is $P(x \pm a) - Px$ or $\pm Pa$. This product Pa is called the *moment* of the couple.

The last-mentioned property will give a high probability of itself to the following theorems, which are the basis of the theory of couples, and can be proved, the first by aid of the composition of forces only, the second by the principle of the lever. Any couple may have the direction of its arm changed, and consequently of its forces, in any manner whatsoever, either in its own plane, or in any plane parallel to it, provided only that the direction in which it tends to turn the system remains unaltered. Secondly, any couple may be replaced by another which has the same moment, the plane and direction of turning remaining unaltered; that is, the arm may be shortened or lengthened in any manner, provided the forces be increased or diminished in the same proportion. If the system were in equilibrium before, it will remain in equilibrium, however its couples may be altered, in any manner described in the above theorems. Hence it follows that a couple is entirely given when there are given:—1. Its axis or any line perpendicular to its plane, which is also perpendicular to any of the planes into which it may be removed. 2. The moment of the couple; specific forces or arms are unnecessary for its description, so long as their product is given. 3. The direction in which it tends to turn the system. The easiest way of describing a couple is then as follows; suppose, for example, a horizontal one:—Take any vertical line for the axis of the couple; on that axis lay down a line proportional to its moment, and agree that vertical lines drawn upwards shall represent moments tending to turn the system from west to east; and downwards, those tending to turn the system from east to west. But a sign must also be agreed upon; positive moment must consist in tendency to turn in one direction, and negative in the other.

The composition and resolution of couples is easily shown to be done in a manner which perfectly resembles that of ROTATIONS. When the couples can have a common axis (act in the same plane or parallel planes), the moment of the resultant is, in sign and magnitude, the sum of the moments of the components, with their proper signs. To find the resultant of two couples which cannot have a common axis, take axes to them which pass through the same point, and on these axes lay down lines representing the moments of the couples in their proper direction. On those lines complete a parallelogram; the direction of the diagonal is the axis of the resulting couple, and its length represents the moment of that couple. Care must be taken to lay down the directions of the moments properly on the axes; the best isolated rule (when reference is not made to distinct co-ordinate planes) is as follows: Let the parts of the plane of the axes which lie in the angle made by the lines representing moments be turned by the two couples in opposite directions. To the student to whom such a direction would be useful, we should say, appeal in all cases to the perceptions derived from ROTATION.

To apply the preceding theorems to the statics of a rigid body, we first take the following conventions:—Assume an origin and three rectangular axes of co-ordinates, as usual. Let the forces which act at each point of the system be decomposed into three, parallel to the axes of x, y, and z. Let each force be called positive, when it acts towards the positive part of the axis to which it is parallel; if, for instance, the axis of z be vertical, and if its positive part tend upwards, all forces in the direction of z, wherever they act, are called positive while they act upwards, and negative when downwards. As to couples, let their moments be called positive when, acting in the planes of x and y, y and z, z and x, they tend to turn the positive part of the first-named towards the positive part of the second (xy, yz, zx). Let P_1 be the first point of the system; let its co-ordinates be x_1, y_1, z_1; let the forces in the three directions acting at that point be X_1, Y_1, Z_1. Let P_2 be the second point; x_2, y_2, z_2, its co-ordinates; X_2, Y_2, Z_2, the forces there applied; and so on. All co-ordinates and forces have their proper signs. At the origin apply the following pairs of equilibrating forces: X_1 and $-X_1$, Y_1 and $-Y_1$, Z_1 and $-Z_1$; X_2 and $-X_2$, Y_2 and $-Y_2$, Z_2 and $-Z_2$, and so on; which of course do not affect the equilibrium, and are over and above those already applied. Again, at the extremity of x_1, in the axis of x, apply the equilibrating forces $Y_1, -Y_1$; at the extremity of y_1, in the axis of y, apply $Z_1, -Z_1$; at the extremity of z_1, in the axis of z, apply $X_1, -X_1$; and so on for the other points, Lastly, let the points of application of the original forces X_1, Y_1, Z_1, be changed so that each shall act at the projection of the point of application made by its co-ordinate; and the same for the other points. Nothing is done but the application of mutually destroying forces, or the change of the point of application of a force to another point in its direction, and the following figure will show the present arrangement for one point. The original forces, transferred, are marked X, Y, Z; the original point of application, P; and the other forces, equilibrating two and two, have great and small letters at their extremities.



We now see that the forces X, Y, Z, are equivalent to—

1. The forces X, Y, Z (marked A, B, C) applied at the origin.
2. A pair of couples to the axis of z (L, b) (X, n), the first positive with the moment Yx, the second negative with the moment Xy. These two are equivalent to one couple with the moment $Yx - Xy$.

3. A pair of couples to the axis of x (M, c) (Y, l), the total moment of which is $\mathrm{Z}y - \mathrm{Y}z$.

4. A pair of couples to the axis of y (N, a) (Z, m), the total moment of which is $\mathrm{X}z - \mathrm{Z}x$.

Apply this to every point in the system, and let $\Sigma\mathrm{X}$ stand for $\mathrm{X}_1 + \mathrm{X}_2 +$, &c., and so on: hence it appears that the whole of the forces are equivalent to forces $\Sigma\mathrm{X}$, $\Sigma\mathrm{Y}$, $\Sigma\mathrm{Z}$, applied at the origin in the directions of x, y, and z, together with couples in the planes of xy, yz, zx, of which the moments are—

$$\Sigma(\mathrm{Y}x - \mathrm{X}y),\ \Sigma(\mathrm{Z}y - \mathrm{Y}z),\ \Sigma(\mathrm{X}z - \mathrm{Z}x).$$

$$\begin{aligned} \text{Let } \mathrm{A} &= \Sigma\mathrm{X},\ \mathrm{L} = \Sigma(\mathrm{Z}y - \mathrm{Y}z) \\ \mathrm{B} &= \Sigma\mathrm{Y},\ \mathrm{M} = \Sigma(\mathrm{X}z - \mathrm{Z}x) \\ \mathrm{C} &= \Sigma\mathrm{Z},\ \mathrm{N} = \Sigma(\mathrm{Y}x - \mathrm{X}y) \\ \mathrm{V} &= \sqrt{(\mathrm{A}^2 + \mathrm{B}^2 + \mathrm{C}^2)},\ \mathrm{W} = \sqrt{(\mathrm{L}^2 + \mathrm{M}^2 + \mathrm{N}^2)} \end{aligned}$$

Then it appears that all the forces can be reduced to one force, V, acting at the origin, making angles with the axes whose cosines are $\mathrm{A} : \mathrm{V}$, $\mathrm{B} : \mathrm{V}$, $\mathrm{C} : \mathrm{V}$; and one couple having a moment W, and whose axis makes with the axes of co-ordinates angles whose cosines are $\mathrm{L} : \mathrm{W}$, $\mathrm{M} : \mathrm{W}$, $\mathrm{N} : \mathrm{W}$. But when there is equilibrium, both the force and the moment of the couple must vanish, for the single force cannot equilibrate a couple. Consequently the conditions of equilibrium are $\mathrm{V} = 0$, $\mathrm{W} = 0$, which give $\mathrm{A} = 0, \mathrm{B} = 0, \mathrm{C} = 0, \mathrm{L} = 0, \mathrm{M} = 0, \mathrm{N} = 0$, the six well-known conditions of equilibrium.

The forces will have a single resultant when V falls in the plane of the couple whose moment is W; that is, when the direction of V is at right angles to the axis of the couple. This takes place when $\mathrm{AL} + \mathrm{BM} + \mathrm{CN} = 0$, a well-known condition.

(For further information, we may refer to Poinsot's *Elémens de Statique*; or, in English, to Pratt's *Mathematical Principles of Natural Philosophy*; or Pritchard's *Theory of Couples*.)

THEORY OF EQUATIONS. Under this term is expressed all that part of algebra which treats of the properties of rational and integral functions of a single variable, such as $ax + b$, $ax^2 + bx + c$, $ax^3 + bx^2 + cx + e$, and so on; a, b, c, &c., being any algebraical quantities, positive or negative, whole or fractional, real or imaginary. Unless however the contrary be specified, it is usual to suppose these co-efficients real, not imaginary.

The great question of the earlier algebraists was the finding of a value for the variable which should make the expression equal to a given number or fraction: as what must x be so that $3x^2 + 2x$ may be 11, or $x^3 - x^2 + 6x$ may be 40, and so on. In modern form it would be asked what value of x will make $3x^2 + 2x - 11 = 0$, or $x^3 - x^2 + 6x - 40 = 0$, and so on. To find values of a variable which should make an expression vanish, or become equal to nothing, was then the first desideratum; and these values are now called *roots* of the expressions. Later algebraists made the finding of these roots subservient to the discovery of other properties of the expressions.

The Hindu algebraists communicated to the Arabs, and through them to the Italians, the complete solution of equations of the first and second degrees. The Italians added the solution of equations of the third degree, and of the fourth imperfectly. These last two degrees have been completed in more recent times, so that it may be now said that the equations of the first four degrees have been completely conquered: that is to say, having given the equation $ax^4 + bx^3 + cx^2 + ex + f = 0$, an algebraical expression can be found, having four values, and four values only, and being a function of a, b, c, e, f, which being substituted for x on the first side of the equation, shall make that first side vanish. But the student would look in vain through the books of algebra to see this expression: it is both complicated and useless, and it is more desirable to indicate how it is to be found, than to find it.

The equation of the fifth degree was attempted in all quarters, without success: means were found of approximating to the arithmetical value of one or another root in any one given equation; but never a definite function of the co-efficients which would apply in all cases. A proof was given by Abel, in Crelle's Journal (reprinted in his works), that such an expression was impossible, but this proof was not generally received: it was admitted by Sir W. Hamilton, who illustrated the argument at great length in the 'Transactions' of the Royal Irish Academy, vol. xviii., part ii.; but the singular complexity of the reasoning will probably prevent most persons from attending to the subject. We do not mean in this article to enter into the history of the theory of equations, but only to place its general state before the reader by an exhibition of the principal theorems, without proof. For works on the subject we may refer as follows:—Hutton, 'Tracts,' vol. ii., tract 33, which contains a full account of the earlier algebraists; Peacock, "Report on certain Parts of Analysis," in the 'Report of the Third Meeting of the British Association;' or the recent works of Murphy, Young, or Hymers; all of which are good, and written on such different plans that any one who makes a particular study of the subject will find it advantageous to consult them all. In French the standard works are those of Budan, Lagrange, and Fourier, which however all treat of particular topics: the algebraical treatises of Bourdon and Lefebvre de Fourcy treat it more generally.

The particular points relative to equations of the first four degrees are as follows:—

1. The expression of the first degree can be reduced to the form $ax + b$; it vanishes when $x = -b : a$, and has only this one root. And $ax + b$ is of the same sign as a or not, according as x is greater or less than the root.

2. The expression of the second degree is more important. It can always be reduced to the form $ax^2 + bx + c$, and its properties are best developed by transforming the preceding into

$$\frac{(2ax + b)^2 + 4ac - b^2}{4a}$$

There are three distinct cases, according as b^2 is greater than, equal to, or less than, $4ac$.

When $b^2 > 4ac$, the expression $ax^2 + bx + c$ has two real and differing roots, contained in the formula*

$$\frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

and has always the same sign as a, except when x lies between those roots. Every change of signs in passing from a to b and from b to c indicates a positive root, and every continuation a negative root: and when one root is positive and one root negative, the positive or negative root is numerically the greater, according as (a, b) shows a change or continuation. When $x = -b : 2a$, the expression is at its numerical maximum between the two roots, its then value being $(4ac - b^2) : 4a$.

When $b^2 = 4ac$, the expression $ax^2 + bx + c$ is a perfect square with respect to x, and absolutely so if a be a square. The two roots become equal, and each equal to $-b : 2a$. The expression now never differs in sign from a.

When $b^2 < 4ac$, the two roots become imaginary, the expression always has the sign of a, and is numerically least when $x = -b : 2a$, being then $(4ac - b^2) : 4a$.

3. The equation of the third degree (or cubic) has been separately considered in the article IRREDUCIBLE CASE.

4. Nothing belongs particularly to the equation of the fourth degree (or biquadratic) except the recital of the various modes in which the solution is reduced to that of a cubic. The various modes are distinguished by the names of their inventors.

Ferrari. Let $x^4 + ax^2 + b + c = 0$. This can be transformed into

$$(x^2 + v)^2 = (2v - a)\,x^2 - bx + v^2 - c:$$

make the second side a perfect square; that is, find the value of v from $b^2 = 4\,(v^2 - c)\,(2v - a)$, or

$$8v^3 - 4av^2 - 8cv + 4ac - b^2 = 0;$$

the extraction of the square root then reduces the biquadratic to a couple of quadratics.

Des Cartes. Let $x^4 + ax^2 + bx + c = (x^2 + \sqrt{p}\,.\,x + f)\,(x^2 - \sqrt{p}\,.\,x + g)$, which gives

$$g + f - p = a,\ (g - f)\sqrt{p} = b,\ fg = c, \text{ or}$$

$$p^3 + 2ap^2 + (a^2 - 4c)\,p - b^2 = 0:$$

find a positive root of this equation (it certainly has *one*), and from it find g and f; then the roots of $x^2 + \sqrt{p}.\,x + f = 0$, and $x^2 - \sqrt{p}.\,x + g = 0$, are those of the given equation.

Thomas Simpson gave a modification of Ferrari's method, and Euler one of that of Des Cartes. (Murphy's Theory of Equations ('Library of Useful Knowledge'), pp. 54, 55.)

The theory of equations of all degrees is to be divided into two distinct parts; the numerical solution, and the general properties of the roots and the expressions themselves. The *numerical solution* must be carefully distinguished from the *general solution*; the former term applying to any mode of approximating to a single root, the latter to any mode of exhibiting a general expression for the roots. We shall begin by the general properties of the roots: the expression in question being ϕx, or

$$a_0x^n + a_1x^{n-1} + a_2x^{n-2} + \ldots. + a_{n-1}x + a_n.$$

1. If r be a root of ϕx, or if $\phi r = 0$, then ϕx is divisible by $x - r$, and the quotient is another such expression of the $(n-1)$th degree, every root of which is also a root of ϕx, and every number which is not a root (r excepted) is not a root of ϕx. Hence ϕx cannot have more roots than it has dimensions, or cannot have more than n roots.

2. When the expression ϕx is divisible by $(x - r)^m$, it is said to have m roots each equal to r; and when this is the case, the substitution of $r + y$ for x would give an expression in which y^m is the lowest power of y.

3. Every expression has as many roots as it has dimensions. This

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* This formula should be committed to memory, and quadratic equations always solved by it. Nothing is more amusing than the vitality of the old method of completing the square and extracting the root in every particular case. No doubt a student should have some training in this last-mentioned process; but his ultimate method should be that of remembering, once for all, the formula in the text.

proposition is of complex proof, but it begins to occupy its proper place in elementary works, especially on the continent.

4. We may now refer to Sturm's Theorem, to Fourier's theorem (given in the article just cited), to Des Cartes' theorem, a very limited particular case of Fourier's, and to Horner's adaptation of, and addition to, the old method of numerical solution by Vieta (an account of the history of this last problem is given in the 'Companion to the Almanac' for 1839). [Involution and Evolution.] We have then, since the beginning of this century, a complete theoretical mode of determining the number of roots, real or imaginary, between any given limits; both exceedingly difficult in the complication of the operations which they require. Also, a mode of easy application, though not theoretically perfect, of determining the limits between which the real roots lie; and a process for the numerical solution which places that question upon the same footing as the common extraction of square, cube, &c., roots; making those extractions themselves, except only in the case of the square root, much easier than before. In Cauchy's theorem, now beginning to be generally known, and which was given in the 'Penny Cyclopædia,' we have a theoretical mode of determining the imaginary roots. And Horner's method has been extended to their computation. But it seldom happens that the actual determination of imaginary roots is required.

5. The Newtonian method of approximation is in the following theorem. If a be nearly a root of $\phi x=0$, and if $\phi a : \phi' a$ be small, then

$$a - \frac{\phi a}{\phi' a}$$

is more nearly a root. See Approximation for the use of this, and Taylor's Theorem, for a more extensive result. But the use of Horner's method is very much more easy than that of Newton: the former, in fact, includes and systematises the latter. But this remark applies only to algebraical equations: for all others Newton's form just given remains practically unamended.

6. We refer to the article Root for the solution of $x \pm 1 = 0$. The following equation, $x^{2n} \pm 2 \cos \theta . x^n + 1 = 0$, admits of complete solution on the same principles.

7. If ϕa and ϕb have different signs, one or some other odd number of roots of ϕx lies between a and b: but if they have the same signs, either no one or an even number of roots lies between a and b. Every equation of an odd degree has at least one real root, negative or positive, according as the first and last terms have like or unlike signs. Every equation of an even degree having the first and last terms of unlike signs has at least two real roots, one positive and one negative.

8. If all the coefficients of ϕx be real, and one of the two, $a \pm b \sqrt{-1}$, be a root, so is the other: and if all the coefficients be rational, and one of the two, $a \pm \sqrt{b}$, a and b being rational, be a root, so is the other. If there be a rational fractional root, its denominator must be a divisor of the first coefficient, and its numerator of the last, as soon as the equation $\phi x = 0$ is cleared of fractions. N.B. Among the divisors of a number we reckon 1 and itself.

9. In the equation $a_0 x^n + a_1 x^{n-1} + a_2 x^{n-2} + \ldots + a_{n-1} x + a_n = 0$, the sum of all the roots is $- a_1 : a_0$, the sum of the products of every two is $a_2 : a_0$, that of the products of every three is $- a_3 : a_0$, and so on. Finally the product of all the roots is $\pm a_n : a_0$, according as n is even or odd. And if $r_1, r_2, \ldots r_n$ be the roots, then $a_0 x^n + \ldots$ is the same as $a_0 (x - r_1)(x - r_2) \ldots . (x - r_n)$.

10. If the preceding expression be called ϕx, and $n a_0 x^{n-1} + (n-1) a_1 x^{n-1} + \ldots$, its derived function, be called $\phi' x$, we have

$$\frac{\phi' x}{\phi x} = \frac{1}{x - r_1} + \frac{1}{x - r_2} + \ldots . + \frac{1}{x - r_n};$$

and if ψx be any rational or integral algebraical function of x, the sum $\psi r_1 + \psi r_2 + \ldots . + \psi r_n$ is the coefficient of the highest power of x in the remainder of the division of $\phi' x \times \psi x$ by ϕx.

11. If s_n in all cases stand for the sum of the nth powers of the roots of the equation, we have

$$s_0 = n,\ a_0 s_1 + a_1 = 0,\ a_0 s_2 + a_1 s_1 + 2a_2 = 0,\ a_0 s_3 + a_1 s_2 + a_2 s_1 + 3a_3 = 0,$$

and so on up to

$$a_0 s_n + a_1 s_{n-1} + a_2 s_{n-2} + \ldots . + n a_n = 0,$$

after which, in all cases,

$$a_0 s_{n+k} + a_1 s_{n+k-1} + \ldots . \quad + a_n s_k = 0.$$

Hence also the coefficients of the expression may be found in terms of $s_1\ s_2 \ldots\ s_n$, as soon as a_0 is given.

12. All rational symmetrical functions of the roots may be easily expressed in terms $S_1\ S_2$, &c., and thence in terms of the coefficients of the expression.

13. If it be required to find a function ψy the roots of which shall be given functions of those of ϕx, so that in all cases $y = Fx$, proceed as in finding the highest common divisor of ϕx and $Fx - y$, and take for ψy the final remainder. But if this final remainder should be of a higher dimension than, from the known number of its roots, it ought to be, it will be a sign that some of the factors introduced in the process have affected the remainder, and these must be examined and removed. The treatment of this case belongs to the general question of elimination, but the following particular cases are almost all that are necessary.

14. To decrease all the roots of ϕx by a given quantity, or to make $y = x - a$, or $x = y + a$, observe that the resulting equation must be

$$\phi a + \phi' a . y + \frac{\phi'' a}{2} y^2 + \ldots . + \frac{\phi^{(n)} a}{2 . 3 \ldots n} y^n = 0;$$

where the coefficients ϕa, $\phi' a$, $\frac{1}{2} \phi'' a$, &c., may be the most readily found by the process described in Involution. The same process may be applied, by using $- a$ instead of a, to increase all the roots of ϕx by a given quantity. It is by this process that the second term of an equation is taken away; thus, the equation being $a_0 x^n + a_1 x^{n-1} + \ldots 0$, assume

$$y = x + \frac{1}{n} \frac{a_1}{a_0}$$

the sum of the roots of the equation in x being $-a_1 : a_0$, that of the equation in y will be 0.

15. To multiply all the roots of an equation by m, multiply its successive terms, beginning from the highest, by $1, m, m^2, m^3$, &c. And to divide all the roots of an equation by m, multiply all the terms by the same, beginning from the lowest. N.B. Terms apparently missing in an equation must never be neglected. Thus $x^7 - 2x^4 + 3x - 1 = 0$ ought to be written

$$x^7 + 0x^6 + 0x^5 - 2x^4 + 0x^3 + 0x^2 + 3x - 1 = 0.$$

This caution is of the utmost importance: in fact no process ought to be applied to any equation without a moment's thought as to whether all the terms be formally written down, and if not, whether the process about to be applied will not require it.

16. To change the signs of all the roots of an equation, change the signs of the coefficients of all the odd powers, or of all the even powers, as most convenient.

17. To change an equation into another whose roots shall be reciprocals of the former roots, for every power of x write its complement to the highest dimension. Thus in an equation of the seventh degree, for x^0 write x^7, for x write x^6, for x^2 write x^5, and so on: lastly, for x^7 write x^0. N.B. Consider the independent term of the equation as affected by x^0. From the reciprocal equation can be found the sums of the negative powers of the roots of the original.

18. The old methods of finding limits to the magnitude of the positive and negative roots of an equation are so rapid that they can hardly be said to be superseded by those of Sturm or Fourier. In enunciating them we speak of coefficients absolutely, without their signs, when mentioning any increase or decrease they are to receive.

If A be the greatest of all the quotients made by dividing the coefficients by the first co-efficient, no root, positive or negative, is numerically so great as $A + 1$. And if B be the greatest of all the quotients made by dividing the co-efficients by the last co-efficient, no root, positive or negative, is numerically so small as $1 : (B + 1)$. Better thus: if L be the first co-efficient, M the greatest, and N the last, signs not considered, then all the roots, numerically speaking, lie between

$$\frac{M + L}{L} \text{ and } \frac{N}{M + N}.$$

19. If L be the first co-efficient, and M the greatest co-efficient which has a different sign from that of L, no positive root is so great as $(M + L) : L$. And if L be the last co-efficient and M the greatest which has a different sign, no positive root is so small as $L : (M + L)$. And to apply this to the negative roots, change the signs of all the roots of the original (§ 16), and find limits to the positive roots of the new one.

20. If L be the first co-efficient, M the *greatest* which has a different sign, and if the *first* which has a different sign be in the mth place from the first term exclusive, or belong to the $(m + 1)$th term; then no positive root is so great as

$$1 + \sqrt[m]{\left(\frac{M}{L}\right)}$$

If k be the number of terms which elapse at the beginning before a change of sign, L the least of their co-efficients, and M the greatest co-efficient of a different sign, any value of x which, being > 1, makes

$$x^{n-k+1} (Lx^k - L - M) + M$$

positive, is greater than the greatest root: for instance,

$$x = \sqrt[k]{\frac{L + M}{L}}.$$

The following method is very convenient when the number of terms is large. Divide the whole expression into successive positive and negative lots, $A_p - B_q + C_r - D_s + \ldots p, q, r, s$, &c., representing the last exponent of x in each lot. Divide $A_p - B_q$ by x^q, and ascertain a value of x, say λ, which makes $A_p - B_q$ positive and equal to l. Do the same with $lx^q + C_r - D_s$, which, for $x = \mu$ (perhaps no greater than λ) becomes m. Repeat the process with $mx^s + E_t - F_u$, and so on to the end. The last value of x used is greater than any root of the equation : and the first value of x, λ, is very often the last also.

21. If each co-efficient which differs in sign from the first term, be divided by the sum of all which precede and agree with the first term (the first term itself included), the greatest resulting fraction, increased by unity, is greater than any positive root of the equation.

22. Newton's method of finding a limit greater than the greatest positive root of any equation now merges in Fourier's theorem. It consists in finding a by inspection and trial, so that ϕa, $\phi' a$, $\phi'' a$, &c., shall all be positive.

23. Any mode of ascertaining a limit greater than the greatest positive root of an equation may be thus treated. Apply it to the reciprocal equation (§ 17), and the reciprocal of the result attained is less than the least positive root of the original. Apply both to the equation of roots with signs changed, and the results give limits for the negative roots of the original.

24. A celebrated mode of examining the roots of equations, but too complicated for ordinary use, consists in forming the equation whose roots are the squares of the differences of the roots of the original. Any quantity being found less than the least positive root of this new equation, its square root is less than the difference of any two roots of the original. If such a quantity could be readily found, the theoretical imperfection of Fourier's theorem would be greatly diminished, and, practically speaking, much advantage would be gained in numerical solution. What is wanted to add to both Fourier's and Horner's method, is a ready mode of finding out when two roots are nearly equal.

25. Lagrange's mode of approximation is as follows :—Having found that a root of an equation lies between the integers a and $a+1$, diminish all the roots of that equation by a, and take the reciprocal equation to the result. Find a root of the last lying between the integers b and $b+1$, diminish all the roots by b, and take the reciprocal equation of the result. Find a root of this last between c and $c+1$, and proceed in the same way. Then the continued fraction

$$\frac{1}{a+}\;\frac{1}{b+}\;\frac{1}{c+},\ \text{\&c.}$$

is a root of the original. The details of the work are much abridged by use of Horner's process.

26. When an equation has equal roots, those roots can be found by an equation depending entirely on the different sets of equal roots. If ϕx have m roots equal to a, $\phi' x$ has $m-1$ of them, $\phi'' x$ has $m-2$ of them, and so on; finally, $\phi^{(m-1)}x$ has one of them. If then ϕx and $\phi' x$ be found to have a common measure, every root of that common measure enters in ϕx one time more than in the common measure itself.

27. When an equation has an integer root, which must be one of the divisors of the last co-efficient, it may be discovered by successive trial, as follows : — Suppose $a_0x^4+a_1x^3+a_2x^2+a_3x+a_4=0$, a_0, &c., being integers. Let k be a divisor of a_4, and let $a_4 : k=l$, an integer. Then if k be a root, we have $a_0k^3+a_1k^2+a_2k+a_3+l=0$, and a_3+l is divisible by k, giving m, an integer. Hence $a_0k^2+a_1k+a\ +m=0$, and a_2+m divided by k gives an integer, say n. Hence $a_0k+a_1+n=0$, and a_1+n divided by k gives $-a_0$. If all these conditions be fulfilled, k is a root. All the divisors of a_4 being tried in this manner, settle the question of the integer roots entirely.

28. If the co-efficients of an equation read backwards and forwards be the same, both in sign and magnitude, every root has its reciprocal also among the roots. By reducing it to the form

$$p+q\left(x+\frac{1}{x}\right)+r\left(x^2+\frac{1}{x^2}\right)+\ldots=0$$

which can always be done by division, when the dimension is even, and assuming $y=x+x^{-1}$, an equation of the $2n$th degree can be reduced to one of the nth and n quadratics. But when the dimension is odd, either -1 or $+1$ must be a root, and the equation can be depressed to an even degree by division by $x+1$ or $x-1$.

The student who is acquainted with the preceding results, namely, such as are either stated or referred to in this article, will find no difficulty either in reading on the history of this subject, or in its application. It is peculiarly a subject on which selection should be made for the beginner.

THERIACA (Θηριακά) was the name given orginally by the ancients to all those medicines which were intended as antidotes to the bite of venomous animals (*θήρια*), as those which counteracted poisonous drugs were called *ἀλεξιφάρμακα* (Galen, 'Comment. in Hippocr.' 'De Alim.,' lib. iii., cap. 7, tom. xv., p. 279, ed. Kühn; id., 'Comment. in Hippocr.' 'De Morb. Vulgar. VI.,' lib. vi., cap. 5, tom. xvii., pt. ii., p. 337); afterwards, however, the word seems to have been somewhat restricted in its signification, or at least *θηριακή* (in the singular number) is applied to one particular compound, while at the same time this one drug was considered to be a safeguard not only against the bites of venomous animals, but also against poisonous drugs and unwholesome food. (Galen, 'De Antid.,' lib. i., c. 1, tom. xiv., p. 1.) Many of these old preparations are preserved in the writings of the ancient physicians, but of these it will be enough to mention here the two most famous, namely the *Mithridatium* (Μιθοιδάτειον, or Ἀντίδοτος Μιθριδάτειος) and the *Theriaca Andromachi.*

The Mithridatium received its name from the great Mithridates, king of Pontus, who had a strange affectation of superior skill in the powers of simples. He tried the effects of these upon condemned malefactors, and, finding that different drugs counteracted different poisons, he thought that, by putting all of them together, he should be able to make a compound that would render him secure against any poison that could be given him. (Galen, 'De Antid.,' p. 2.) Accordingly he is commonly said to have so fortified his own body by the constant use of this antidote, that he afterwards tried in vain to put an end to his life; but this, if true, "was probably," as Dr. Heberden says ('Antither.,' p. 10), "less owing to the strength of his antidote than to the weakness of his poison."

Andromachus the Elder (who was physician to the emperor Nero, and the first person who is known to have received the title of *Archiater*) made considerable alterations in the Mithridatium by omitting some of the ingredients, adding others (especially the dried flesh of vipers), and by increasing the proportion of opium. His receipt was embodied in a Greek elegiac poem, in order that it might be the more easily preserved without alteration; and this has been inserted by Galen in two of his works ('De Antid.,' lib. i., cap. vi., et 'De Ther. ad Pison.,' c. 6), and has been frequently published in a separate form. Andromachus likewise changed the name of the Mithridatium thus reformed to *γαλήνη*; but in Trajan's time it obtained that of 'Theriaca,' either from the vipers in it, or from its good effects in curing the bites of venomous animals. (Galen, 'De Antid.,' lib. i., cap. 6; 'De Ther. ad Pison.,' cap. 5., tom. xiv., pp. 32, 232.) The formula for the Theriaca of Andromachus, as well as for others, is to be found in Geiger's 'Pharmac. Universalis. Pars. Posterior,' p. 281.

It is much to be regretted that the word 'Theriaca' is applied to the uncrystallisable juice which flows from sugar in the process of refining; for distinction's sake this should always be termed "Faex Sacchari," or "Syrupus Empyreumaticus," anglicé, "Molasses," as in the Dublin 'Pharmacopœia.' The uses of molasses (or melasses) are well known.

THERMÆ. [BATHS.]

THERMOCHROSIS. [RADIATION OF HEAT.]

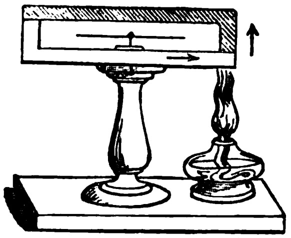
THERMO-ELECTRICITY. It has been shown, under GALVANISM, that any obstruction to the passage of an electric current produces heat in the conductor; so conversely it has been found that any obstruction to the equal propagation of heat in a conducting circuit produces a currrent of electricity. The discovery of this principle was made in 1822, by Dr. Seebeck of Berlin, while engaged in researches concerning electro-magnetism, which but two years before had been discovered by Professor Oersted of Copenhagen; and the name thermo-electricity was given to the fluid by the latter philosopher in order to distinguish it from that which is produced by the usual galvanic apparatus, which he proposed to call *hydro*-electricity.

Some of the most simple experiments by which the effects of thermo-electricity may be illustrated are those which, soon after the discovery, were made by Professor Moll of Utrecht. ('Edinburgh Philosophical Journal,' No. xvii.) A slip of copper bent in the form of a semicircle was attached (in close contact), at its extremities, to the ends of a bar of antimony about 15 inches long; and the bar being laid in the direction of the magnetic meridian with the wire above it, a small compass needle was suspended, or supported on a pivot between them. On heating the northern extremity of the bar by the flame of a lamp, the north end of the needle was observed to deviate towards the west. Again, when a slip of zinc and one of copper were bent so that, on the extremities being applied together, there was formed a parallelogram having the junctions of the slips in the middle of the shorter sides, and a compass needle was suspended within the circuit, on placing the apparatus in a plane coinciding with the magnetic meridian, with the longer sides parallel to the horizon (the copper slip being uppermost) and heating the northern point of junction, the needle deviated towards the west: the apparatus being inverted so that the zinc slip was uppermost, on heating the northern junction as before, the needle deviated towards the east. It follows from these experiments that the fluid current, if such it be, which affects the magnetism of the needle, circulates about the copper slip in such a manner that when the latter is in a horizontal position its direction is from west to east, passing above the slip, in a plane perpendicular to its length: this effect is similar to that which takes place, though in a contrary direction, when a magnetised needle is brought near a conducting wire joining the poles of an ordinary galvanic apparatus; for if the conducting wire be placed in a horizontal position in the direction of the magnetic meridian, with the copper, or the negative end of the apparatus towards the north, and the needle be below the wire, the north end of the needle deviates towards the east; if above the wire, towards the west.

Effects similar to those which result from the application of heat take place when one extremity of the bar of antimony, or one of the junctions of the zinc and copper, is made colder than the other by means of ice.

When both ends of the bar were heated, no deviation was produced in the needle; and after deviation had taken place by heating one end only of the bar, in proportion as the heat tended to a uniform diffusion, the needle gradually returned to the direction of the magnetic meridian.

The following figure shows the general arrangement of these experiments. A rectangle is composed of antimony (shaded) and bismuth.



On heating one of the junctions a thermo-electric current will set in in the direction of the arrows and the needle will be deflected.

Thermo-electric circuits may be formed in a ring consisting of two curved bars of different metals, as bismuth and copper, each being in the form of a semicircle, and the two being attached together in the direction of a diameter; or they may be produced in a rectangle made by placing in close contact four bars of metal, of two different kinds, following one another alternately. M. Oersted formed a hexagonal circuit with six pieces, three of bismuth and three of antimony, which were disposed in alternate order: on heating, by means of a spirit-lamp, one of the places of junction in the ring, or in the rectangle of four pieces, a compass-needle placed within or below the plane of circuit was found to deviate; and it deviated still more when the opposite angles of the rectangle were heated. In the experiment with the hexagonal circuit the deviation was greater in proportion to the number of alternate joints which were heated. Similar effects were produced when the alternate joints were artificially cooled; but the deviation was the greatest when the alternate joints were heated and the others were cooled.

By doubling the lengths of the bars in a rectangle composed of four, the deviation was less than that which was produced by the smaller rectangle; but when the larger rectangle was composed of eight pieces, the deviation was greater.

In this country the subject of thermo-electricity was pursued by Professor Cumming of Cambridge, who appears to have entered upon it without any other knowledge of the discovery of Seebeck than the simple fact that electro-magnetical action was produced by heating one end of a bar of antimony, to the extremities of which were made fast those of a brass wire. The details of his researches are published in the 'Cambridge Philosophical Transactions,' for 1823. From these it appears that all perfect conductors of electricity, on being heated or cooled in any part, exhibit in general magnetical phenomena; but the intensity of the action, which is indicated by the amount of the deviations produced in a magnetised needle, is not the same in all substances, and with some the direction of the current is contrary to that which is produced in others. When a single bar, of symmetrical form, is heated in the middle, it produces no effect on the needle, probably because the opposing currents counteract each other; and in a ring formed of two metals, when heated at one of the points of junction, the fluid seems to pass from one metal to the other; so that one loses positive electricity, or becomes negative, while the other becomes positive. If, however, the ends of a sensitive galvanometer be united by means of a platinum wire, no current will be perceived on heating the wire until a portion of it be twisted into a loop; the molecular tension thus produced will interfere with the conducting power of the wire, and a current will flow through the apparatus from right to left when heat is applied close to the loop and to the right of it. Or if the wire be formed into two flat spirals, and one be heated to redness, and brought into contact with the cold spiral, a current will flow from the hotter to the colder portion. Or if portions of a metallic wire be stretched by weights while other portions are free, a current will flow from the former to the latter on applying heat to the junctions. These last-named facts are due to Professor W. Thomson.

Professor Cumming having ascertained from experiments on bars of bismuth, which were made alternately hot and cold, and were placed in contact with each other (each pair of the hot and cold parts, and also the two extremities of the whole compound bar, being connected together by wires), that the action of the whole bar on a needle was greater than that of any two portions, one hot and the other cold, was led to the discovery that electro-magnetism may be exhibited by the mere juxtaposition of an indefinite number of small plates. He was also enabled to determine the thermo-electric relations of different metals by merely placing in contact with each other a small portion of each of the two kinds of metal to be examined, and touching first one of them, and then the other, with one end of a silver or copper wire which was connected with the heated bar. When the metals were bismuth and antimony, the former, on being touched, caused the compass-needle to deviate so as to indicate positive electricity, and the latter so as to indicate negative electricity; and in the memoir above quoted there is given a table of the electrical relations of metals in several different combinations. In the same memoir there is also an account of several curious anomalies which were observed in the magnetic action: one of these is, that when iron wire is used to touch the metals examined, of which one is iron, the needle deviates a certain number of degrees in the positive direction; then, as the heat of the wire is increased, the deviation in that direction gradually diminishes till it becomes zero; after which the deviation takes place in a negative direction, and it becomes a maximum in this direction when the wire acquires a red heat.

Metals with a marked crystalline structure, and an inferior power for conducting electricity, display thermo-electric effects most perfectly. Thus bismuth and antimony are favourable metals, and even the warmth of the hand applied to one of the junctions of a pair will deflect the galvanometer needle. Indeed for small differences in temperature, no instrument is so sensitive as a thermo-electric pile or thermo-multiplier. An instrument of this kind was invented by Cumming, and improved by Nobili, who introduced the astatic needle into it.

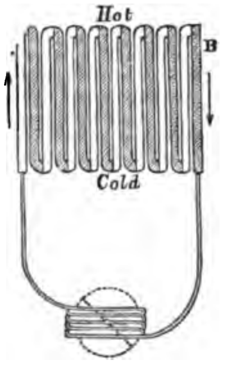
If a thermo-electric pair have one of its junctions kept at 32°, whilst the other junction is gradually raised in temperature, the current will gradually increase in intensity up to a certain point, then decline, and become reversed. If, for example, the metals be zinc and silver, the current will decline at 248°, then cease, and set in, in the opposite direction as the temperature continues to rise. This probably arises from the effect of heat on the crystalline structure of zinc. Iron and antimony produce the same effect to a less extent. The thermo-electric order of the metals is quite different from their voltaic order. It is for a few of the principal metals as follows:—

Bismuth.
Platinum.
Lead.
Tin.
Copper and Silver.
Zinc.
Iron.
Antimony.

but for further details, see Matthiessen, 'Phil. Trans.', 1858.

Thermo-electric circuits have been formed between non-metallic bodies. Thus the point of a heated cone of porcelain clay, brought into contact with a cold cylinder of the same material, and connected with the galvanometer by means of moistened cotton, caused a deflection of the needle. This effect has been ascribed to the mutual re-action of two portions of water of different temperatures.

Thermo-multiplier.—Bars of antimony and bismuth A and B may be arranged into a thermo-multiplier or thermo-electric pile, so that a high temperature may be applied to one series of junctions and a low one to the other. The current is then measured by its effect on the galvanometer needle, as shown in the figure. By means of a thermo-electric pile chemical effects may be produced, such as decomposing a solution of iodide of potassium, and with one hundred pairs of platinum and iron wire, each 1 inch long and $\frac{1}{100}$th of an inch in diameter, water acidulated with sulphuric acid has been decomposed. Wires of iron and German silver make a very good thermo-electric pile, but in all cases the current is feeble, and the size of the elements do not add to the effect, except by increasing the conducting power. The thermo-electric pile used by Nobili and Melloni formed a very delicate measure of temperature. It consisted of thirty-six pairs of bars of bismuth and antimony packed into a small space, connected with a delicate astatic galvanometer. When the alternate junctions of the bars at each end of the pile were covered with lamp-black the pile was so sensitive to radiant heat as to be affected by the warmth of the hand at a distance of 30 feet. Even the amount of heat radiated by insects could be estimated by means of this apparatus. Mr. Joule placed the instrument in vacuum, with a steel magnet near it to diminish the action of the earth's magnetism, and so far increased its sensibility, as to indicate by means of a single pair of bismuth and antimony, a change of temperature amounting to only the $\frac{1}{1000}$th part of a centigrade degree. By means of this instrument Melloni was able to prove the instantaneous transmission of heat through glass and other bodies, and the thermo-transparency of rock-salt. By its means Forbes was able to show the polarisation of heat. The fineness of the wires used for the junction, together with its great sensibility, allow the use of this instrument, where a common thermometer could not be applied, as in measuring the temperature of the



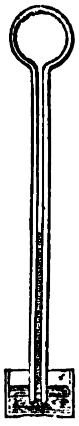
muscles of the human body. It has also been employed by Mr. Joule in confirming the deductions of Professor Thomson's theory of the thermal effects of stretching solid bodies already alluded to. Mr. Joule has found that if a strip of vulcanised india-rubber is stretched by a weight which doubles its length, an elevation of its temperature by 50° C. shortens it by as much as $\frac{1}{10}$th of its whole length; and Peltier has discovered that a cooling effect is produced by an electric current in flowing from bismuth to antimony across a surface of contact. This result has been applied by Professor Thomson to the establishment of a "Mechanical Theory of Thermo-electric Currents" ('Transactions of Royal Society of Edinburgh,' 1851).

The term *pyro-electricity* is sometimes applied to the phenomena produced by heating certain minerals, such as boracite, topaz, axinite, mesotype, tourmaline, prehnite, calamine, and sphene. It was shown by Œpinus, so far back as 1757, that the two electricities are to be found on opposite sides, or ends, of the same piece of tourmaline when heated, and it was proved by Haüy that electric crystals exhibit different sets of crystalline faces on the two sides on which the contrary electric effects are observed. It is remarkable, also, as lately pointed out by Svanberg, that in bismuth and antimony, where there is one particular plane of cleavage more brilliant than the rest, when bars of the metals are placed with this plane of cleavage perpendicular to the direction of the current, such bars are more highly negative than in any other position, whilst if a less brilliant plane of cleavage be placed across the line of current, the bar is more highly positive than in any other position.

THERMO'METER (from the Greek words θερμός, *hot*, and μέτρον, *a measure*) is an instrument by which the temperatures of bodies are ascertained. It consists of a glass tube with a capillary bore containing, in general, alcohol or mercury, which expanding or contracting by variations in the temperature of the atmosphere, or on the instrument being immersed in the liquid or gas which is to be examined, the state of the atmosphere, liquid, or gas, with respect to heat, is indicated by a scale which is either applied to the tube or engraven on its exterior surface.

The end proposed by a thermometer is the measurement of the temperature of any body with relation to the temperature of some other substance, as of water at the point of freezing; but the measure so obtained must not be understood to express the absolute quantity or density of heat in any body, it being well known that different substances, though exhibiting the same apparent temperature, contain very different quantities of heat according to their *capacities* for that element. [SPECIFIC HEAT; LATENT HEAT.]

The thermometer must have been in use in the beginning of the 17th century, but it is not known, precisely, to whom the honour of the invention is due. A physician of Padua, named Santorio, and Cornelius Drebbel, of Alkmaar in Holland, are the persons to one of whom that honour is, with most probability, ascribed; and the former, in his 'Commentaries on Avicenna' (1626), actually claims it for himself. It may, however, have happened with this, as with other scientific discoveries, that the idea of the instrument occurred to two persons or more at or about the same time.


Original Air-Thermometer.

The first thermometers were intended to indicate variations in the temperature of the atmosphere merely; and the most simple of them consisted of a hollow glass-ball at one extremity of a long tube which was open at the opposite extremity. The air within the ball and tube being rarefied by the heat of a lamp, and the tube being in a vertical position, the open end was plunged into a vessel containing a coloured spirit; as the enclosed air cooled, the pressure of the atmosphere on the liquid caused it to ascend in the tube till the expansive force of the air in the ball and the upper part of the tube became equal to the pressure. In this state, an increase of the temperature of the atmosphere caused the air in the ball to expand and press down the spirit in the tube; on the other hand, a diminution of temperature, by causing that air to contract, allowed the external pressure to raise the spirit. A scale was adapted to the tube in order to express the degree of temperature by the number of the graduation at the upper extremity of the spirit.

An effort was made to render the instrument portable by bending the lower part of the tube upwards, and terminating this branch also with a ball; and a small aperture was made in the latter in order that the external air might have access to the lower surface of the spirit. Mr. Boyle subsequently modified the air-thermometer by making the tube quite straight and open at both ends: the lower end was immersed in a small glass vessel containing both air and coloured spirit, and the vessel being formed with a neck which closely encircled the tube, it was hermetically sealed to the latter. The variations in the temperature of the atmosphere caused the air in the vessel to expand or contract, and thus to press with more or less force on the surface of the spirit; the latter was consequently made to ascend or descend in the tube.

The air-thermometer invented by Amontons (1702) consisted of a tube nearly four feet long, open at both ends, and curved upwards at bottom, where it terminated in a ball. This tube carried a column of mercury about 29¼ English inches high, so that the air in the ball was compressed by the weight of two atmospheres. A light body, in which was inserted the lower end of a wire, floated on the upper extremity of the column of mercury in the tube; and near the upper end of the wire was an index by which the number of the graduation on a scale was shown. The variations of the temperature of the air in the ball caused the mercurial column to ascend or descend in the tube; and thus were produced corresponding movements in the index. By this instrument it was proposed to measure high temperatures on a scale whose length was only half of that which was required with the simple air-thermometer.

The defects inseparable from all the above thermometers are, that the dilatations of the air are not proportional to the increments of heat; that the length of the column of spirit or mercury varies with the temperature of the atmosphere; also, that the air which is in contact with the surface of the spirit in the open vessel, in the first kind of instrument, or with the top of the column of the spirit or mercury in the others, exerts more or less pressure according to its density; and thus the indications afforded by the thermometer are rendered erroneous, or require corrections which it is difficult to apply. The air-thermometer proposed by Dubuat, and of which the following is a brief description, possesses some advantages above those which have been mentioned; but not being portable, it has never been employed.

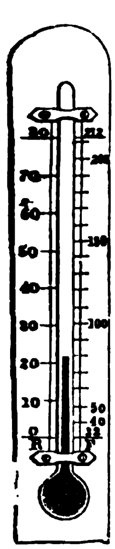
It consists of a column of mercury in a tube, like that of a barometer, hermetically sealed at the upper end, and bent below so as to form a short branch inclined at about 40° to the straight part of the tube; this branch terminating with a hollow ball. The mercury occupies the straight part of the tube to the height of about 29¼ inches above the bend; and at this bend it terminates without entering into the ball, which, by the construction, is a little above the bend. The part of the tube which is above the column of mercury is free from air, and when the bend is plunged in boiling water the tube is to be in a slightly inclined position, so that a vertical line may pass through the two extremities of the mercurial column; then, upon the ball becoming cool, and the elasticity of the air in it being diminished, the weight of the mercury will cause it to descend in the long branch and rise in the other. The mercury is to be prevented from entering the ball by making the tube decline farther from the vertical position, so that the lower extremity of the mercury may remain in the vertical line before mentioned; and the temperature of the air is to be determined by the height of the top of the column of mercury above a horizontal line passing through the lower extremity, that is, by the cosine of the declination of the tube from the vertical. Since the air in the ball preserves constantly the same volume, the elasticity communicated to it by the heat of the atmosphere, or by the fluid in which the instrument is plunged, is always in equilibrio with the pressure of the column of mercury, which is the force acting against it, and is proportional to the vertical height of that column.

About the middle of the 17th century the members of the *Accademia del Cimento* caused thermometers to be constructed in which, instead of air, alcohol or spirit of wine was employed. The fluid was introduced, as at present, into a glass tube terminating at bottom in a hollow ball, from which the air had been expelled by heat. The opposite extremity of the tube was then hermetically sealed, and a scale of equal parts was applied to the stem, by means of small beads of coloured enamel, for the purpose of expressing the temperature of the atmosphere, or of the liquid which was to be examined. Alcohol dilates and contracts considerably with the variations of temperature to which it may be subject, though not in so great a degree as air. It is also capable of measuring very low temperatures; but as it is brought to a boiling state much sooner than water, it cannot be employed to ascertain a high degree of heat. Spirit-thermometers were introduced into this country by Mr. Boyle, and they are still used for low temperatures.

Sir Isaac Newton, being dissatisfied with the smallness of the range of spirit-thermometers, employed linseed-oil in tubes for the purpose of measuring degrees of temperature. This liquid has nearly the same amount of expansibility by increments of heat as alcohol; and it is capable of bearing a considerable amount of heat and of cold without either boiling or freezing; but from its viscidity it adheres so much to the interior side of the tube as to render accurate observations quite impossible, and on this account it has not since Newton's time been employed for thermometers.

The thermometer which is now in general use is a slender tube of glass terminating in a ball containing mercury, the air having been expelled and the tube afterwards hermetically sealed. The idea of employing this fluid for the purpose of measuring degrees of heat by its expansion is supposed to have first occurred to Dr. Halley; and the reason why it was not employed by that philosopher appears to have been that the range of its expansion is much less than that of alcohol. According to Boerhaave ('Elementa Chemiæ,' 1732), the honour of having been the first to recommend a mercurial thermometer is to be ascribed to Römer, the discoverer of the motion of light, who is said to have invented it in 1709; but it was not till the year 1724 that such a thermometer was known in this country. In that year an account of a mercurial thermometer which had been invented by Fahrenheit, of Amsterdam, in 1720, was read before the Royal Society, and was published in the 'Philosophical Transactions' (vol. xxxiii.),

The advantages of mercury over alcohol and air, as a measure of temperature, are that its expansions are more nearly proportional to the increments of heat than those which take place in either of the other fluids; it is easily deprived of air, and its power to conduct heat being considerable, the changes of its volume by changes of temperature in the surrounding medium take place more rapidly than those of any other fluid except the gases.



Fahrenheit's Thermometer.

At first the scales for measuring degrees of temperature were arbitrary, and consequently no two thermometers could be compared together. The scale of the Florentine thermometer was determined by marking the place where the top of the spirit column stood in the tube when the latter was immersed in snow, and the place at which it stood at the time of the greatest heats in Florence: the interval between the points was divided into 60 parts. Subsequently, in this country, Mr. Boyle and Sir Isaac Newton formed scales for determining the expansion of the spirit or oil by making the space included in each degree of the tube equal to a certain portion of the whole volume. Thus, supposing the ball of the thermometer and part of the tube to be divided into 10,000 equal parts, and to be wholly occupied by the oil when the instrument is plunged in melted ice, Sir Isaac found that by the heat of the human body the oil expanded 256 such parts, and by that of boiling water 725 parts; then, considering the point at which the top of the column stood in the tube when the latter was placed in the ice, as the zero of the scale, he divided the interval between this point and that at which the top of the column stood when the ball of the thermometer was placed under the arm of a man, into 12 parts. Afterwards by proportion he found that the distance from the ice-point to that of boiling water was equal to 34 such parts ('Phil. Trans.,' vol. xxii.). This method, being of difficult execution, was soon abandoned.

The scale which has been in general use in this country since the year 1724, is supposed to have been invented by Fahrenheit. It is quite unknown on what ground he made choice of the fixed points on his scale, or of the number of graduations between them; but it is thought that one of the fixed points was that of boiling water, and that the other, which is the zero of the scale, was that at which the top of the column stood when the instrument was exposed to an intense cold in Iceland, in 1709. The extent of the scale between this last point and that of boiling water is divided into 212 parts, and the point of freezing water is at the thirty-second division from the zero point. See the scale on the right of the tube in the above figure.

M. Réaumur constructed a thermometer in which spirit of wine was employed, and he formed a scale in a manner nearly similar to that which had been put in practice by Sir Isaac Newton. He computed the volume of the glass ball, and graduated the tube so that the space between two divisions was equal to one-thousandth part of that volume: he then found the zero of the scale by marking the place where the top of the column stood when the thermometer was placed, in water just freezing: and afterwards, plunging the instrument in boiling water, he observed whether or not the spirit rose exactly eighty divisions. If not, he strengthened or diluted the spirit till it did so; and the point at which the top of the spirit stood became the point of boiling water. Of this instrument an account was published in the 'Mémoires' of the Academy of Sciences for 1730, but the construction has been long since abandoned; for, besides the difficulty of giving a proper degree of strength to the spirit, it is well known that the latter cannot be made to take the temperature of boiling water, so that the determination of the upper point in the scale must be very erroneous. That which is now called Réaumur's thermometer is an improvement on the former, by M. Deluc, who determined the points of freezing and boiling water by experiment, and divided the distance between them into eighty parts, the zero of the scale being at the former point. See the scale on the left of the tube in the above figure.

A third scale, called "Centigrade," has been much in use among the philosophers of the Continent within the last eighty years: it was invented by Celsius, a Swede, and it differs from that of Réaumur or Deluc, only in the distance between the points of freezing and boiling water being divided into 100 parts. The length of each degree in this thermometer, as well as in that of Réaumur, is greater than in the scale of Fahrenheit; and consequently the indications of temperature, when the top of the spirit or mercury is between the lines of division are rather uncertain, from the difficulty of estimating them accurately by the eye; also, the temperatures required to be determined being often below the point of freezing-water, the employment of negative signs is of more frequent occurrence with these thermometers than with those of Fahrenheit.

The following formulæ will serve to convert any given number of degrees on Fahrenheit's scale into the corresponding number of degrees on Réaumur's and the Centigrade scales, and *vice versâ*.

Let F, R, and C express any corresponding numbers of degrees on the three scales respectively: then—

$$(\mathrm{F}-32^\circ)\,\frac{4}{9}=\mathrm{R},\ \text{and}\ (\mathrm{F}-32^\circ)\,\frac{5}{9}=\mathrm{C}:$$

$$\frac{9}{4}\,\mathrm{R}+32=\mathrm{F},\ \text{and}\ \frac{9}{5}\,\mathrm{C}+32=\mathrm{F}:$$

$$\text{also, } \frac{4}{5}\,\mathrm{C}=\mathrm{R},\ \text{and}\ \frac{5}{4}\,\mathrm{R}=\mathrm{C}.$$

N.B. When F is between zero and 32°, the values of R and C are negative, and express the required number of degrees below zero on Réaumur's and the Centigrade scales. Also, when F, R, or C expresses any given number of degrees below zero on its proper scale, it must be considered as negative.

The scale invented by De l'Isle of St. Petersburg, in 1733, being still occasionally in use, it may be necessary to mention that it is formed by making the space included in each degree equal to one hundred-thousandth part of the whole volume of the mercury; the zero of the scale is at the point of boiling-water, and between this point and that of freezing-water the space is divided into 150 parts.

It may be observed that the situation of the freezing-point on the scale of a thermometer can be determined with great accuracy if the ball and part of the tube be immersed in pounded ice; for it is known that water containing ice and snow remains of the same temperature till the ice is entirely dissolved, every accession of heat to the water being employed in promoting the dissolution. But the point of boiling water is far from being so precisely known, since it varies with the density of the atmosphere at the time of making the determination. Distilled water in an open vessel, and under a given pressure of the atmosphere, boils at an invariable temperature, except as far as the nature of the vessel may make some difference; for if the heat communicated to the water be increased, the only effect produced is that of driving off a greater quantity of steam in a given time: in a vessel exhausted of the air the water will boil at a temperature expressed by about 70° of Fahrenheit's scale, while in a vessel constructed so as to prevent the steam from escaping it will remain in a liquid state at a temperature of 400° and upwards. In order therefore that the temperatures indicated by different instruments may agree together, it is recommended that this point should be found from water boiling in the open air at a time, if possible, when the height of the mercurial column in the barometer is 30 inches, and when the temperature of the air is indicated by 55° of Fahrenheit's scale.

This effect of the pressure of the atmosphere on the boiling of water was noticed by Fahrenheit in 1724, and M. Deluc, in his 'Recherches sur les Modifications de l'Atmosphère,' has investigated a formula for determining the height of the boiling-point above the freezing-point of the scale in terms of the height of the mercury in the barometer; but the English artist, Bird, was the first who applied a correction on account of the state of the barometer, for the purpose of fixing the point of boiling water on the scales of thermometers.

The Royal Society having, in 1776, appointed a committee to consider the best means of adjusting the fixed points of thermometers, the formula of Deluc was verified and reduced to English measures for the benefit of artists, in the event of their being obliged to make the instruments under different states of the atmosphere with respect to density and temperature; and the following are some of the corrections which are given by Sir George Shuckburgh for determining the true place of the boiling-point of water. The first column contains the height of the barometer in inches; and the second, the correction which is to be applied with its proper sign to the number 212 on Fahrenheit's scale, in order to give the correct number of degrees at which the water will boil under the pressure expressed by the height of the mercurial column.

Inches.	°
26	−7·09
27	−5·27
28	−3·48
29	−1·72
30	0
31	+1·69

The committee observe that in trying the heat of liquors, the quicksilver in the tube of the thermometer should be heated to the same degree as that in the ball; or if this cannot be done, a correction should be applied on that account. ('Phil. Trans.,' vol. lxvii.)

Thermometer-tubes should have their bores very slender, and, if possible, perfectly equable in the whole of their length. When there is any inequality in the transverse sections, the best artists make the graduations of the scale vary so that they may correspond to the equal divisions of a cylindrical tube; and in order to ascertain the relative dimensions of the sections, they cause a small quantity of mercury, about an inch in length, to slide along the interior of the tube, measuring its length in different places; then, since the lengths are inversely proportional to the areas of the sections, the variations of the former will immediately show the corresponding variations of the latter. The method of *calibration*, as it is called, recommended by the Kew committee, will be noticed presently. It is usual to give to the bore an oval form, with the broader side towards the front, in order that the mercury or spirit may be easily distinguished at a certain distance, as by approaching very near the instrument, the heat of the observer's person may affect the length of the column. Mr. Sheepshanks found that tubes with round bores were far more nearly true than those with flat ones. He also approves of bulbs three or four-tenths of an inch in diameter. They should not be too small, or the graduations of the scale will be close together, nor too large, or the instrument will not be sensitive on account of the large body of mercury required to be heated. The bulb should not be blown by the breath, lest moisture be introduced, but by an india-rubber bag.

It is of course essential that the extent of the thermometer-scale should be great enough to comprehend all the temperatures at which the substances generally required to be examined exist in a state of fluidity; and this extent may be obtained when mercury is employed. According to the experiments of Mr. Dalton, mercury does not boil till it has acquired a temperature equal to 660° of Fahrenheit's scale; and it does not freeze till it is subject to a degree of cold expressed by 39 divisions below the zero of that scale, (—39°) or 71° below the freezing-point of water. Pure alcohol, on the other hand, has never been frozen, though it has been exposed to a degree of cold exceeding that which is expressed by 166° below the zero of Fahrenheit; (−166°) though at that remarkably low temperature it became viscid. Hence a spirit-thermometer is to be preferred to one of mercury when it is intended to ascertain the temperature of the air in high northern or southern latitudes: but since the spirit boils in air with a degree of heat expressed by 173° of Fahrenheit, it is unfit for many of the purposes for which a thermometer is required. For instruments capable of measuring very high temperatures, see PYROMETER.

In the construction of a thermometer, the air should be carefully expelled from the tube, and even from the mercury or spirit within it: the variations in the density of the atmosphere cannot, under proper precaution, affect the instrument, since the tube is hermetically sealed. This precaution consists in not graduating the tube for some months after it has been sealed, or until the glass has accommodated itself to the altered circumstances of a vacuum within and atmospheric pressure without. The most carefully constructed thermometers will shift their fixed points if graduated too soon after filling. It must also be observed that the indications of temperature are not precisely expressed in terms of the dilatation of the mercury or spirit only, but in terms of the excess of that dilatation above the dilatation of glass. The apparent dilatation of mercury in a glass tube is equal to $\frac{1}{64{\cdot}8}$ of its volume, between the temperatures of freezing and boiling water; and its true dilatation between the same limits is $\frac{1}{55{\cdot}08}$ of its volume.

A perfect thermometer would be one in which the expansions of the fluid in the tube were exactly proportional to the increments of heat which it might receive from the substance whose temperature is to be determined; but it cannot be said that any of the fluids which as yet have been employed in the construction of thermometers strictly possess this property. Mercury is the fluid in which it exists in the greatest degree; but from the experiments of Deluc it has been ascertained that, between the points of freezing and boiling-water, the temperature indicated by the mercurial thermometer is lower than the true temperature, the greatest difference (which, however, is only equal to 1°·4 of Réaumur's scale, or 3°·15 Fahrenheit), being in the middle between those two points on the scale. From the same experiments it is also found that when thermometers are regulated so as to agree at the points of freezing and boiling-water, whether the liquid be oil, spirit, or water, the indications are always below those of mercury, the difference being the greatest at the middle between those points. With oil of olives the difference is 1° of Réaumur's scale (2°·25 Fahr.); with highly-rectified alcohol, 4°·9 Réaumur (11°·02 Fahr.); with half alcohol and half water, 6°·7 Réaumur (15°·07 Fahr.); and with water, 19°·5 Réaumur (43°·87 Fahr.). It must be observed that great irregularities take place in the expansion of all fluids when near their boiling state, and that mercury contracts very suddenly when at the point of its congelation. The deviations of the spirit-thermometer from the true indications of heat are known to be rather greater than those of the mercurial thermometer. It may be added, that the alcohol in a thermometer-tube loses, in time, part of its strength; and that, in consequence, the degree of expansion by a given increment of heat is not the same as when the instrument was made. The expansion of alcohol for temperatures greater than about 173° Fahr., at which the spirit boils, cannot be ascertained practically, because the spirit at that temperature passes into a state of vapour; and the comparison between the mercurial and the spirit thermometer ought not to be carried higher than that temperature; or the scales for mercury and spirit ought to be regulated so as to agree with one another at the freezing-point of water and at the temperature of 173° Fahr.; if this were attended to, the differences between the indications of the mercurial and spirit thermometers, above that point, would be less than they appear to be by the tables of Deluc.

Later measurements by Regnault of the total expansion of mercury for three progressive intervals of 180° Fahr., give the following results: Between 32° and 212° it is 1 part in 55·08; between 212° and 392° it is 1 in 54·61; and between 392° and 572° it is 1 in 54·01. In the mercurial thermometer it may be assumed, without sensible error, that between 32° and 212° equal increments of heat raise the thermometer through an equal number of degrees. The increase in the capacity of the glass bulb (especially for crown glass) almost exactly compensates for the increasing rate of the expansion of mercury, although for temperatures above 212° the compensation is not so exact. It has been found, also, that the temperature of 572° Fahr., as measured by an air thermometer, is 586° by a mercurial thermometer, on account of the increasing dilatation of mercury, with an increased temperature. Mr. Dixon, in his 'Treatise on Heat,' says: "Different glasses have different co-efficients of expansion, and also vary in the law of their dilatation at high temperatures, and as the amount of absolute dilatation of mercury is small, this variation in the expansion of the glass envelope produces irregularities of considerable magnitude in the apparent dilatation of mercury. As the real expansibility of air is much greater, its apparent expansion in glass is not affected to the same extent by these variations in the rate of expansion of the latter, and accordingly in an air-thermometer the rate of expansion of the glass may be considered as sensibly uniform. When corrected, therefore, for the expansion of its envelope, such an instrument forms the most perfect thermometer with which we are acquainted in the present state of science." An air-thermometer, corrected for the expansion of its envelope, being compared with a mercurial thermometer made with the peculiar description of glass employed by M. Regnault, the agreement between the two instruments was perfect up to 200° C.; whereas, in a mercurial thermometer made of ordinary tube, compared with one of crystal glass, although they agreed from 0° to 100° C., yet at higher temperatures the discrepancies were:—

1st Thermometer.	2nd Thermometer.	Difference.
190·51	191·66	1·15
246·68	249·36	2·68
251·87	254·57	2·70
279·08	282·50	3·42
310·69	315·28	4·59
333·72	340·07	6·35

Water, like other substances, suffers a diminution of volume by the abstraction of heat, but when it is cooled to a temperature between 39° and 40° of Fahrenheit's scale, it seems to have attained the maximum of density; and if the process of cooling be continued, it then increases in volume till it is converted into ice. Therefore, if a thermometer were made with water, and the top of the column were at 50° Fahr., it would be impossible to know whether the temperature were 50° or 30°, the expansion being nearly equal at equal distances within 10° above and below 40° of the scale. The cause is uncertain, but it is probably owing to a partial crystallisation, which may begin to take place in water when at a temperature expressed by about 8° above its freezing-point.

The mercurial and spirit thermometers formerly differed considerably at temperatures below that of freezing water. By observations made during Sir Edward Parry's second voyage, the differences between the indications of the spirit and mercurial thermometers varied from 3°·05 to 8° Fahr. between the temperatures +58° and −30°, the alcohol being always too low. At very low temperatures alcohol thermometers, unless very carefully prepared, differ greatly among themselves. Dr. Kane in his Arctic voyage records temperatures as low as from —60° to −75°; but he admits that "it was not uncommon for thermometers which had given us correct and agreeing temperatures as low as —40° to show at —60° differences of from fifteen to twenty degrees." In remarkable contrast with this are the results obtained by Sir E. Belcher in his Arctic voyage with the thermometers furnished to him by Mr. Welsh of the Kew Observatory. While wintering in Northumberland Sound, 76° 52′ N., 97° W., he made a comparison of seven thermometers, marked 2, 6, 8, 20, 3, 4, 5, with a standard instrument, with the following results. The temperatures were all natural ones:—

Standard.	2.	6.	8.	20.	3.	4.	5.
Fahr.	°	°	°	°	°	°	°
—20°	—21	—20	—20·6	—21·2	—20·4	—20·7	—21·1
—30°	—31	—30	—30	—31·5	—30·8	—31·2	—31·5
—40°	—40·5	—39·6	—39·8	—40·5	—40·5	—39·5	—41·3
—50°	—50	—49	—49	—51	—49	—49·3	—51·9

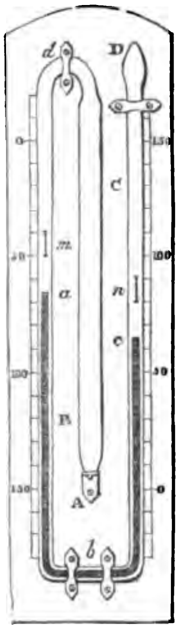
The lowest temperature observed was on 12th January, 1853, namely —62°·5. The indices of the minimum thermometers read next day at 8 A.M., gave —62°, —61°·6, −66°, −63°·2. "The night was bright and calm; no sensation of cold. —63°·2 is the external exposed thermometer, but was never read excepting by its index of that graduation." Parry's coldest was —54° for 15½ hours. In Belcher's Expedition, the following temperatures were observed:—

—46°	and below,	for	150	continuous	hours.
—50°	,,	,,	89	,,	,,
—52°	,,	,,	88	,,	,,
—55°	,,	,,	52	,,	,,
—58° to 62°·5			14	,,	,,

In the preparation of spirit thermometers the alcohol should be *absolute*, and the stem should be deprived of air by boiling. When the instrument is intended to mark very low temperatures, it is desirable to graduate it by means of two fixed points, namely, the freezing point of water (32°) and the freezing point of mercury (−39°). Professor Miller has also proposed a third fixed point, namely, the fusion of solid carbonic acid when it shall have been determined. The very low artificial temperatures that have been recorded must not be insisted upon, as the law of contraction of alcohol (which seems to form a converging series) is not yet accurately known, and upon it the indications of the spirit thermometer must of course depend. Even the low natural temperatures which are sometimes recorded, are not always trustworthy. During the severe cold of the winter of 1860-61, some very low readings have been proved to be erroneous, in consequence of the distillation of a portion of the spirit in the minimum thermometer into the further extremity of the horizontal stem. It has been shown that such a thermometer requires to be tilted from time to time to connect this portion of alcohol with that in the stem, unless indeed the new make come into general use, in which the end of the stem is turned upwards, and the stem itself a little raised in the frame.

Register Thermometers.—It is of great importance in meteorology that the observer should be able to ascertain the highest or lowest point of a thermometer scale at which the column of mercury may have stood during his absence; and a very large number of contrivances have been made to obtain this end. Of these, one, which is not quite gone out of use, was invented by Mr. Six, whose name the instrument bears, and is described in the 'Philosophical Transactions' for 1782. We retain it in this place, as it shows the principle of construction in a very large number of register thermometers. Six's contrivance consists of a long tube bent so as to form three parallel branches, A, B, and C: the part A is an elongated bulb, and the rest of the tube has a capillary bore. The lower portion, *b*, contains mercury, which rises in B and C to certain points, as *a* and *c*, and the bulb is filled with spirit of wine, which passing over the bend at *d*, descends to the upper extremity of the mercury in B: above *c* the branch C is also filled with spirit to near the upper extremity, which is hermetically sealed.

Two small indices of steel coated with glass, which are represented at *m* and *n*, are introduced in the branches B and C: these are capable of being forced upwards by the rising of the column of mercury in either tube, and they have about them a fine wire or a bristle or a thread of glass; so that they will remain stationary where they happen to be when the heads *a* and *c* of the columns recede from them. Their lower extremities consequently indicate the points at which the ends of the columns may have stood before such recession.



Six's Register Thermometer.

It is evident that the expansion of the spirit in A by increments of heat will cause that which is in B to press down the column of mercury in that branch and force up the extremity *c*, moving the index *n* before it, while by its friction the index *m* is prevented from descending. On the other hand, the contraction of the spirit in A allows the elasticity of the air in the ball D to force the column in C downwards, the index *n* remaining at the highest point to which it had been previously raised; the mercury in B then rises up, carrying the index *m* before it, till an augmentation of temperature causes the spirit in A to expand, and again force the mercury in B downwards.

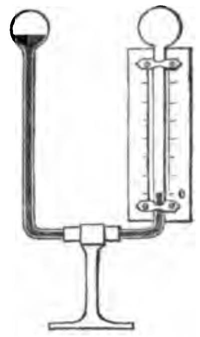
The graduations on the scale belonging to branch C are numbered upwards; while the graduations on the scale belonging to B are numbered downwards. The points *a* and *c* should always indicate the same degree on the two scales; and by means of a magnet the indices *m* and *n* may be brought down to those points: from thence afterwards the former ascends by a decrease, and the latter by an increase of temperature.

This instrument is apt to get out of order, and has given way to simpler forms. The *maximum* thermometer, as now generally made, is a mercurial thermometer with a horizontal stem. Within the bore is a small piece of steel wire, which is pushed forward by the expanding mercury, and is left stationary when the mercury begins to contract and recede, thus marking the highest temperature in the absence of the observer. The instrument can be reset for another observation, by tilting it, or by applying a magnet to the outside of the stem. The *minimum* thermometer is arranged like the maximum, only it contains coloured alcohol, the index being a small piece of enamel terminating in a bead, and resting just below the surface of the liquid column. As the liquid contracts by cold it carries the index with it by capillary adhesion, but as soon as the liquid begins to expand, it passes by the enamel, and leaves it at the lowest point to which the liquid had descended, thus marking the minimum temperature. To reset the instrument it may be tilted a little forward, or the enamel may contain a piece of iron wire, which can be acted on by a magnet on the outside. Another form of maximum thermometer, by Negretti, is to contract the tube just above the bulb, so as to allow the mercury to pass when it expands, but not to return when it contracts. The maximum temperature is thus marked, and the instrument can be reset by giving it a slight swing. The advantage of this instrument is that there is no index to get out of order, but there is some trouble in determining the corrections necessary to bring its readings into unison with a standard thermometer. Professor Phillips has a maximum thermometer, in which a portion of the mercurial column is detached from the rest by means of a small bubble of air, which detached portion remains stationary in the tube when the mercury in the bulb contracts, and thus marks the highest reading. The instrument is reset by swinging or inclining it. A good minimum thermometer may still be considered as a desideratum. Messrs. Negretti and Zambra have contrived one of very ingenious construction, in which a slender-pointed needle is brought down to the surface of the mercury in the tube, the latter being of wide bore, and in a vertical position. As the mercury contracts the needle descends with it, but on rising the mercury presses the needle to the glass, and rises up by the side of it, instead of raising it. There are difficulties in the manufacture of this instrument, and also in the method of observing it, and all we can say of it is, that it is under trial. The introduction of photographic registration [SELF-REGISTERING INSTRUMENTS] in meteorological observatories has greatly limited the necessity for mechanical registration. Even the wet and dry bulb thermometers [HYGROMETER] are now registered photographically.

The *Chromatic Thermometer* is a contrivance by Sir D. Brewster, in which a number of superposed plates of glass exert under differences of temperature a polarising action, which is estimated when the plates are held in a beam of light polarised by reflection.

Wollaston's Thermometer, for determining heights by variations in the boiling point of water, is described under BOILING OF LIQUIDS.

Differential Thermometer.—This instrument, which was invented by M. Sturmius, of Altdorf, before the year 1676, and was revived by Professor Leslie, in 1804, consists of two thermometer tubes, terminating, at one extremity of each, in a hollow glass ball, and containing coloured sulphuric acid: the opposite extremities are united by the flame of a blow-pipe, and an enlargement of the bore is made at the place of junction. The tube is then bent so as to form three sides of a rectangle, the two balls, which are of equal diameter, forming the upper extremities of two sides; and the instrument is on a stand with the branches of the tube in vertical positions. When the temperature of the air in the two balls is the same, the acid occupies one side and the base, and rises a little way up the other side of the rectangle. To the latter side is attached a graduated scale, with the zero of which the upper extremity of the acid in that branch should coincide. In the event of this adjustment being deranged, it may be restored by causing a small quantity of air to pass from one ball to the other, which is done simply by the warmth of a hand applied to that ball from whence the air is to be driven.



Differential Thermometer, invented by M. Sturmius of Altdorf.

The variations of temperature in the apartment will evidently have no effect on the instrument, since the action upon the two balls will be equal: but if one ball alone be heated, the rise of the acid in the other will immediately indicate the difference between the temperatures of the media about the two balls by the excess of the expansion of the air in one ball above the expansion in the other. The delicacy of the instrument is such that the least difference of temperature is immediately made sensible by the movement of the acid.

Radiating Thermometer, or Actinometer.—For the purpose of measuring the intensity of solar or terrestrial radiation, an instrument, called an ACTINOMETER, has been contrived, for the use of which we must refer to that head; but it may be remarked that an approximation to the measure of solar radiation may be obtained by simply exposing a register thermometer with a blackened ball to the direct action of the sun's rays. [RADIATION.] The thermometer should be placed a few inches above the ground, and be screened from currents of air; and the graduations should be made on the stem of the thermometer, in order to avoid the errors arising from the expansion or warping of the scale. The force of terrestrial radiation may be measured by the minimum temperature of a register thermometer, whose ball is placed in the focus of a concave mirror: the face of the mirror is to be turned towards the face of the sky, but away from the rays of the sun.

Since the establishment of the Kew Observatory, the construction of meteorological instruments has received the earnest attention of competent minds. Under BAROMETER will be found the method by which the Kew standard was formed by Mr. Welsh, the late superintendent. He has also given directions for the construction and comparison of thermometers; his Report, presented to the Royal Society in 1852 (and printed not in the 'Transactions' but in the 'Abstracts of the Papers,' &c.,*), being founded in great measure on the plan proposed by M. Regnault. Our limits will not allow us to do more than just indicate the methods adopted. And *first*, as to the *calibration* of the tube. A short column of mercury (less than 1 inch in length) having been introduced into it, the tube is attached to the frame of Perreaux's dividing engine, and, by means of flexible tubing, is connected at both ends with india-rubber air-bags, the pressure on which is regulated by screws. The mercury is brought to that part of the tube where the graduation is to be commenced. The cutting-frame of the engine carries a small microscope with cross-wires in its focus; on turning the dividing-screw, the microscope wire is made to coincide with the first extremity of the mercury, and the screw is then turned forward until the wire reaches the second extremity; so that the length of the column is thus given in revolutions of the screw. The mercury is then made to move along the tube by pressing on one of the india-rubber bags until the first end again coincides with the microscope wire, when the length of the column is again measured, and the mercury again moved forward: this process is repeated until the column has been measured for each length of itself through the whole extent of the proposed scale. Permanent marks are made on the glass at the points of commencement and ending of calibration. If the progress of the numbers shows any considerable irregularity in the tube, and as a verification of the first set of measures, the calibration may be repeated, commencing at a point one-half the length of the column in advance of the original starting point. A series of measures interpolated from the two sets may then be adopted. In this operation the mercury should be very pure and the tubes clean. *Secondly*, with respect to the *graduation*, measured lengths of the column of mercury, in its successive steps along the tube, correspond to equal volumes, so that assuming the calibre of the tube not to vary throughout the small length of the calibrating column, it is evident that by dividing the spaces occupied successively by the mercury into an equal number of parts, the divisions will represent the same capacity, although they may be of different lengths. Before making the tube into a thermometer, the divisions of the scale may be verified by introducing a longer column of mercury, and examining whether the column occupies an equal number of divisions in different parts of the scale. Should there be any irregularity, a table of corrections is to be formed, but this is seldom required. The divisions are cut with a fine needle-point upon a coating of engraver's varnish, and are afterwards etched by means of hydro-fluoric acid. The required dimensions of the bulb may be found approximately by weighing a measured length of the mercurial column, and from the known expansion of mercury and its specific gravity, computing the capacity of the bulb. *Thirdly*, as to the determination of the scale co-efficients. The thermometer being properly filled with mercury and sealed, the divisions of the scale evidently represent equal increments of the volume of the fluid, but their value is quite arbitrary. The advantage of this plan is, that the divisions can be tested before the instrument is converted into a thermometer. The instrument is kept sufficiently long to allow of the settlement of the freezing point. The tendency of this point to shift, if the graduation take place soon after the filling, has already been noticed, but Mr. Welsh has pointed out another peculiarity in this respect: after a thermometer has been exposed for some weeks to the ordinary temperature of the air, if its freezing point be ascertained, and it be suddenly exposed for a short time to the temperature of boiling water, and again immediately placed in ice, the latter determination of the freezing point will be lower than the former, by as much as from 0°·1 to 0°·2, and the freezing point does not recover its former position for some time, probably two or three weeks. The freezing point is found by placing the thermometer in finely pounded ice, from which the water is drained off as it melts. The boiling point is taken at the temperature of steam (from distilled water) of the same elasticity as that of the atmosphere. The barometer is observed at the time, and the correction to a uniform height of 30 inches (reduced to 32°) is found from Regnault's Table. The fixed points are determined in the position in which the thermometers are to be used.

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* See also British Association Report, 1853.

In the graduation of mercurial thermometers, it is customary to consider increments of volume as proportional to increments of temperature, a plan which cannot be adopted in the case of spirit thermometers. In testing some spirit thermometers graduated for low temperatures (namely, to −75° Fahr.) intended for the Arctic Expedition under Sir E. Belcher, Mr. Welsh proceeded to determine the rate of expansion of alcohol in glass, as compared with that of mercury. The alcohol had been carefully prepared by Prof. Miller, and its specific gravity at 60° was 0·796. A tube was calibrated and divided with an arbitrary scale, and its divisions were found upon verification to be of exactly equal capacity throughout. The tube was then furnished with a bulb of the same dimensions as those intended to be supplied to the Admiralty, and was filled with alcohol. Comparisons were then made between the readings of this instrument and those of a standard mercurial thermometer through as wide a range as was found practicable. The comparisons above the freezing point were taken in water: those below 32° were taken in freezing mixtures of ice and salt, or chloride of calcium. From these comparisons the law of expansion was deduced, but for the details we must refer to Mr. Welsh's report.

The apparatus used at Kew for comparing the indications of different thermometers consists of a cylindrical glass vessel, 15 inches deep, and 8½ inches diameter, together with a stand for supporting the thermometers, and an agitator or flat ring of tinned iron, fitting easily within the vase, for agitating the water so as to preserve an equable temperature throughout. The stand is a vertical rod supported by a small tripod, resting on the bottom of the vessel. Hooks sliding on this rod serve for suspending the thermometers. These are arranged with their bulbs at the same height in a circle of 3 inches diameter round the rod, and are kept fixed by means of elastic bands to a projecting six-rayed frame, attached to the supporting rod. In this way six thermometers can be compared at once. The whole apparatus is placed on a wooden revolving stand, and in taking the observations, the observer first agitates the water briskly for some time, then turns the revolving stand until each thermometer is brought opposite to his eye, and he reads off the scales as quickly as possible to an assistant, who takes down the numbers. The six thermometers can be read off and recorded in 20 seconds. More than one set of readings should be made for each temperature, and the order of observing the instruments should be reversed, to avoid, as much as possible, the changes which may occur during the reading off.

In graduating a thermometer for meteorological purposes, the freezing point is determined as usual with melting ice or snow, and an upper reading is fixed, by placing the thermometer in water of a certain temperature, together with a standard instrument. Instruments are now sold which have undergone comparison with the standards of the Kew Observatory, and as their price is moderate, there is no reason why the observations made by amateurs in various parts of the kingdom should not be accurate, and comparable with each other. The scales are engraved on the tubes, so that no correction is required for the scale. When the instrument is intended to record the external temperature, it should be placed in the shade away from the reflected and radiated heat of walls and buildings, and the bulb should be kept perfectly dry. Convenient thermometer stands have been contrived by Mr. Glaisher, Mr. Lawson, and Dr. Drew, for sheltering the instruments from disturbing influences. The best hours for observation are 9 a.m., 3 p.m., and 9 p.m. The readings should be taken rapidly, especially in cold weather, to prevent the warmth of the body from influencing them.

THERMO-MULTIPLIER. [THERMO-ELECTRICITY.]

THERMO-PHONE. When a bar of copper slightly curved and furnished with a wire for a handle, is heated, and its convex surface placed on a notch cut in the upper surface of a stout ring of lead resting on a sounding board, it will vibrate and evolve a variety of musical sounds resembling those of an æolian harp, and also the drone of the bagpipes, changing in the most fitful and irregular manner, and varying with the pressure applied by means of a point to the concave surface of the copper. The sounds will continue until the temperatures of the lead and the copper approach each other. Such an arrangement is called a *thermo-phone*. The experiment succeeds best with metals whose conducting powers for heat are very different, such as copper and lead, the conducting power of the former being = 845, and of the latter = 287 (silver = 1000). The experiment, which is due to Mr. Trevelyan, was investigated by Professor Forbes ('Phil. Journal'), who showed that it could be performed with various other metals of different conducting powers, and the subject has been more recently investigated by Professor Tyndal ('Phil. Trans.')

THERMOSTAT, or *heat-governor*, is an apparatus invented and patented in 1831 by Dr. Ure, for regulating temperature in the processes of vaporisation and distillation, in heating baths and hothouses, in adjusting the draught of stoves and furnaces, in ventilating apartments, &c. It acts upon the principle that when two thin metallic bars, of different degrees of expansibility, are riveted or soldered side by side, any change of temperature will cause a sensible flexure in the compound bar; the side consisting of the least extensible metal becoming concave, and the other convex. By this flexure of the compound bar, which takes place with considerable force, a movement is effected, which, by the intervention of levers, may be made to open or close stop-cocks, dampers, ventilators, or any description of valves, and thereby to regulate the flow of heated liquids or the admission and emission of air. The principle of the thermostat may be applied in many different ways, of which the following may serve as examples. In *fig.* 1, *a* is the compound bar, firmly fixed at *b*. To the other, or free end of the compound bar, is attached, by means of a connecting rod, the short end of a lever mounted upon the axis of a circular revolving valve, or ventilator, *c*; and from the longer end of the lever is sus-

Fig. 1.

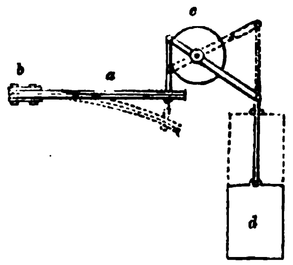
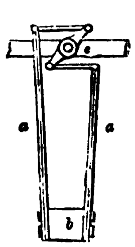


Fig. 2.



pended a sliding valve, or damper, *d*. By increasing the temperature of the chamber or vessel in which the thermostat is placed, the compound bar will assume the curved form indicated by the dotted lines, by which means the position of the lever will be altered, the valve *c* will be turned on its axis, and the damper will be raised. *Fig.* 2 shows another arrangement, in which two compound bars, *a*, *a*, fixed at *b*, are made to open and close a valve, *c*, in a pipe through which air, water, or any other fluid is passed. By increasing the temperature of the apparatus, the upper or moveable ends of the bars would recede from each other, and, consequently, alter the position of the valve. *Fig.* 3 shows the principal part of a thermostatic apparatus in which three pairs of compound bars, *a*, *a*, *a*, are used to give motion to a sliding-rod *d*, *d*, with which any kind of valve may be connected by a rack and pinion, a chain and pulley, or otherwise. *b*, *b*, in this figure, is a straight guide-rod, which is fixed at one end by a screw-nut *c*. The thermostatic bars are nearly or quite straight when cold, and become more or less curved by the action of heat; but in some modifications of the apparatus the bars are always curved, and the action of the apparatus depends upon the increase or decrease of the ordinary flexure. *Fig.* 4, for example, represents a thermostatic hoop, *a*, *a*, which may be immersed horizontally beneath the surface of the water-bath of a still. The hoop is fixed at *b*, and to its free ends are attached short links *c*, *c*, which impart longitudinal motion to the rod *d*. *e* is a lever-handle moved by the sliding-rod, and turning a valve on its axis *f*. The outer end of this lever carries an index, which moves against a graduated scale. *g* is a screw-nut, moveable upon the sliding-rod to adjust the apparatus before graduating the scale or arc traversed by the index. [PYROMETER.]

Fig. 3.

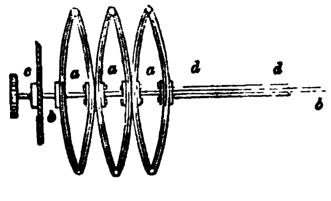
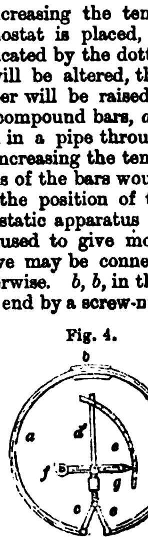


Fig. 4.



THESMOPHO'RIA (θεσμοφόρια), a festival with mysteries in honour of DEMETER, to whom all the institutions of civilised life, especially of civil and religious laws, were attributed. The festival of the Thesmophoria especially referred to this part of the character of the goddess, as is clear from several of the ceremonies observed at its celebration, and from the surname of the goddess, "Thesmophoros," from which the festival derived its name. It was celebrated in various towns in Greece, and in the Greek colonies, as Sparta, Thebes, Eretria, Ephesus, Syracuse, Agrigentum, and others. But the place where it was held with the greatest solemnity, and where the particulars of its celebration are best known, was Athens. It was introduced at Athens, according to some writers, by Orpheus, and according to Herodotus (ii. 171) by the daughters of Danaus from Egypt. Its celebration was confined to women, especially married women. It commenced every year on the 11th of Pyanepsion, and lasted three days, though some writers extend it to four or even five. The discrepancy in this case, as well as in that of other Greek and Roman festivals, seems to have arisen from the circumstance that the real festival was in many instances preceded by one or more days devoted to preparations and purifications, and that some writers reckoned these days as belonging to the festival.

Previous to its celebration, the women of each demos elected from among themselves two matrons to conduct the solemnities, whose husbands, provided they had received a dowry of not less than three talents, had to pay the expenses of the festival as a liturgy. (Isæus, 'De Cironis Heredit.,' p. 208). The first day of the festival was called *ἄνοδος* or *κάθοδος*, that is, the procession; because the womon went from Athens to Eleusis in a procession in which they carried on their heads certain laws (*θεσμοί*) written either in books or upon tablets. During the night between the first and second day the women solemnised their mysteries at Eleusis. The second day, called *νηστεία*, or "The Fast," was a day of mourning, on which the women were not allowed to take any other food than cakes of sesame and honey, and the greater part of it they spent sitting in mournful attitudes on the ground around the statue of the goddess. Meursius and others think that the procession to the Thesmophorion (the temple of Demeter Thesmophoros) at Athens, which is alluded to by Aristophanes ('Thesmophor.,' 276, &c.), and in which the women walked behind a waggon laden with baskets containing mystic symbols, took place in the afternoon of this day, the whole of which was a sacred day at Athens, on which neither the senate nor the people were allowed to hold their usual meetings. The third day was called *καλλιγένεια*, a surname of Demeter, by which she was invoked on this occasion. (Aristoph., 'Thesmophor.,' 296, with the Scholiast.) On this day the women made up for the day of mourning, and indulged in various kinds of merriment, in imitation of Iambe, who was believed to have created a smile on the face of the goddess during her grief.

THESSALONIANS, EPISTLES TO THE. Christianity was introduced among the Thessalonians in A.D. 50, by St. Paul, when he first passed over from Asia Minor into Europe to preach the gospel. St. Paul found at Thessalonica a synagogue of the Jews, "and went in unto them, and for three Sabbath days reasoned with them out of the Scriptures," endeavouring to convince them that Jesus was the Christ or Messiah expected by them. Though some of them believed, his success with the Jews does not appear to have been great; but a considerable number of the "devout Gentiles" were converted, and many women of distinction; so that the Christian church at Thessalonica was composed both of Jews and Gentiles, of whom the latter were the more numerous. The unconverted Jews stirred up a persecution against him, so that himself and his companions "were sent away by night by the brethren" to the neighbouring city of Berœa. Here, again, the Jews of Thessalonica stirred up a tumult against St. Paul, so that he was obliged to retire to Athens, leaving, however, Silas and Timothy at Berœa. At Athens he was subsequently joined by them, and being anxious about his recent converts at Thessalonica, "when he could no longer forbear" (1 Thes., iii., 1), he sent Timothy from Athens "to establish them, and to comfort them concerning the faith." St. Paul then visited Corinth, and on the return of Timothy with "good tidings of their faith and charity, and that they had a good remembrance of him always" (1 Thes., iii. 6), he wrote his first epistle to them, A.D. 52, from Corinth, and not from Athens, as the subscription of the epistle imports.

It was one of the earliest, if not the very first, of all St. Paul's epistles, the doubt lying between this epistle and that to the Corinthians, written from the same place. That to the Galatians was also probably written from Corinth before the Second Epistle to the Thessalonians. The genuineness of the first epistle has always been admitted: together with the second epistle, it is quoted and recognised as the work of St. Paul, by Irenæus, Clement of Alexandria, Tertullian, Origen, and all subsequent ecclesiastical writers. The immediate occasion of St. Paul's writing this epistle was the favourable intelligence brought by Timothy of the steadiness with which the Thessalonians adhered to Christianity, in spite of the persecution with which they were assailed by their own countrymen. Besides being exposed to direct persecution, there can be little doubt that they were also in danger of being moved by the reasonings of their religious adversaries, to which the sudden disappearance of St. Paul from Thessalonica, and his apparent desertion of them at a critical moment, might give some plausibility and apparent confirmation. To counteract the natural result of all this was one of the chief objects of Timothy's mission, and the First Epistle to the Thessalonians was written with the same design. Accordingly, in chap. i., after a short introduction, in which he couples the names of Timothy and Sylvanus (the Roman form of Silas) with his own, he expresses his thankfulness for their "work of faith and labour of love, and patience of hope in the Lord Jesus Christ," and then (v. 5–10) reminds them of the "proofs of power and of the Holy Ghost" with which the preaching of the gospel among them was accompanied, as evidences of its truth, and commends them for the constancy of their faith.

The Second Epistle to the Thessalonians was undoubtedly written soon after the first; Sylvanus and Timothy being joined with the apostle in the inscription of this Epistle as well as of the former; and as in chap. iii., ver. 2, he requests the prayers of the Thessalonians for his deliverance from wicked men, it is not improbable that he wrote it soon after the insurrection of the Jews at Corinth, when they dragged him before Gallio, and accused him of persuading men to worship God contrary to the law. This Epistle seems to have been occasioned by the information which St. Paul received on the state of the church at Thessalonica from the messenger who conveyed his first letter to the elders of the church, and his report of the effect produced by its contents. From some expressions in that Epistle (iv. 15; v. 4–6), compared with chapter ii. of the second, it would seem that a number of Thessalonians had come to the conclusion that the day of judgment was at hand, and would happen in their generation. To correct this misapprehension, and to prevent the anxiety and the neglect of secular affairs which resulted from it, appears to have been the main object and design of St. Paul in writing this Second Epistle to them.

This Second Epistle to the Thessalonians is, next to that to Philemon, the shortest of St. Paul's Epistles, but not inferior to any in style or spirit, and it is also remarkable as containing a distinct prophecy of the corruptions and delusions which were to arise in the Christian Church.

The undesigned coincidences between these Epistles and the "Acts of the Apostles" are given in Paley's "Horæ Paulinæ."

THIACETIC ACID (HS, $C_4H_3O_2S$). The product of the action of tersulphide or pentasulphide of phosphorus upon monohydrated acetic acid. It is a colourless liquid, possessing at the same time an odour of acetic acid and a sulphurous smell. It unites with bases, and may also be made to yield an anhydride—*thiacetic anhydride* ($C_4H_3O_2S + C_4H_3O_2S$).

THIACETONINE ($C_{12}H_{10}(C_2H_3)_3NS_4$). An artificial organic base produced by the simultaneous action of ammonia and sulphuretted hydrogen upon acetone.

THIALDINE ($C_{12}H_{13}NS_4$). An alkaloid produced by the action of sulphuretted hydrogen upon aldehydide of ammonium. It is volatile and crystalline, very slightly soluble in water, but readily so in alcohol and in ether. It forms crystalline salts with acids. A similar base containing selenium in the place of sulphur and termed *selenaldine*, may be prepared by an analogous process.

THIANISOL ($C_{16}H_8O_2S_2$). *Hydride of sulphanisyl.* A white pulverulent organic substance, formed by the action of hydrosulphate of ammonia upon hydride of azoanisyl.

THIN PLATES. [UNDULATORY THEORY.]

THIOFORMYLIC ACID ($C_2H_2O_2S_2$?). A crystalline body, formed by the action of dry sulphuretted hydrogen upon formiate of lead. It possesses a slightly alliaceous odour, and is insoluble in water, but freely soluble in boiling alcohol and ether. Its alcoholic solution does not redden litmus paper, and it has not yet been made to form definite salts.

THIOFURFOL ($C_{10}H_4O_2S_4$). An unimportant organic substance, formed by the action of hydrosulphate of ammonia upon solution of furfurol.

THIONAPHTHAMIC ACID. [NAPHTHALIC GROUP.]

THIONAPHTHIC ACID. [NAPHTHALIC GROUP.]

THIONESSALE. [STILBENE.]

THIONURIC ACID. [URIC ACID.]

THIOSALICOL. [SALICYLIC GROUP.]

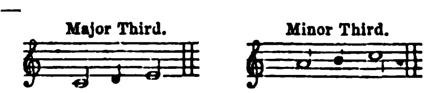
THIOSINAMINE ($C_8H_8N_2S_2$). *Rhodalline.* A compound of ammonia with the oil of mustard, or sulphocyanide of allyl. It crystallises in brilliant white right rhombic prisms, which are inodorous and bitter. Thiosinamine is easily soluble in hot water, in alcohol, and in ether. It forms salts which are very instable and rarely crystalline. Treated with oxide of mercury it yields *sinamine*:

$$\underbrace{C_8H_8N_2S_2}_{\text{Thiosinamine.}} + HgO_2 = \underbrace{C_8H_6N_2}_{\text{Sinamine.}} + HgS_2 + 2HO.$$

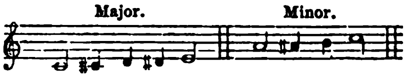
Treated with ethylamine instead of ammonia, oil of mustard yields *thiosinethylamine* ($C_{12}H_{12}N_2S_2$). Whilst by treatment with oxide of mercury the latter body yields *sinethylamine* ($C_{12}H_{10}N_2$). [MUSTARD, OIL OF.]

THIOSINETHYLAMINE. [THIOSINAMINE.]

THIRD, an interval in music, classed among the imperfect concords, because liable to alteration; that is, the third part may be either *major* or *minor*. The ratio of the Major Third is 5 : 4; of the Minor Third, 6 : 5. The former comprises one major and one minor tone, as C E. The latter comprises a major tone and a semitone, as A C. Example:—



Or, according to the mode of description adopted by many writers on the subject, the Major Third comprises, inclusively, five semitones; the Minor only four. Example:



THIRLAGE, a tenure or custom formerly very common in Scotland, by which the owners or occupiers of certain lands were compelled to take their corn to a particular mill, to which the lands were said to be thirled or astricted, and to pay a certain proportion of it, varying in different cases, as a remuneration for the grinding, and for the expense of the erection and maintenance of the mill. This kind of servitude, having become in many cases exceedingly oppressive, has fallen very much into disuse.

THISTLE, ORDER OF THE, an ancient Scottish order of knighthood, sometimes called the order of St. Andrew. The claim to a high antiquity rests on no other authority than the legendary account recited in the warrant for the restitution of the order in 1687, and given most minutely by several Scottish antiquaries, attributing its formation to Achaius, king of the Scots, in commemoration of a victory obtained by himself and Hungus, king of the Picts, over Athelstan. Nicolas observes, as a fitting illustration of this legend, that Achaius died upwards of a century before the reign of Athelstan. The investigation of Sir Nicholas Harris Nicolas, in the third volume of his 'History of the Orders of Knighthood of the British Empire,' shows that the Order of the Thistle, as an organised fraternity, did not exist until the reign of James VII. of Scotland and II. of England. The warrant of James II. for the re-institution, as it is styled, of the "most ancient and honourable order of the Thistle," which is printed at full by Nicolas, and which asserts that by authentic proofs, documents, and records, the order "continued in great glory and splendour for many hundreds of years," bears date Windsor, May 29, 1687. Statutes were issued, and eight knights were nominated by James II., but the patent for the restitution of the order never passed the great seal; and on the abdication of James II., the order fell into abeyance, until it was revived by Anne in 1703. The statutes then authorised were much the same as those framed in 1687, and are still in use. The order consisted originally of the king and twelve brethren. This continued without alteration until July 16, 1821, when, in consequence of the coronation of George IV., an ordinance was issued for the appointment of four extra members, who should become regular knights as vacancies should occur; and in May, 1827, the number of knights was permanently extended to sixteen. The decorations worn by the knights consist of a collar of enamelled gold, composed of sixteen thistles, interlaced with sprigs of rue, fastened to the mantle by a white riband; a small image of St. Andrew, also of enamelled gold, suspended from the collar; a medal or badge of gold, having an image of St. Andrew within a circle containing the motto of the order, "NEMO ME IMPUNE LACESSIT" (No one provokes me with impunity), and a thistle; a green riband, to which the medal is attached, and which is thrown diagonally over the left shoulder; and a star, consisting of a St. Andrew's cross of silver in the centre of which is a thistle enamelled in its natural colours upon a field of gold, and surrounded by the motto and rays of silver. The star is worn on the left shoulder, on a mantle of green velvet, which, with other parts of the dress, are minutely described by Nicolas. The officers of the order are the dean, the secretary, the lordly king-at-arms, and the usher of the green rod, each of whom receives an annual salary, and a fee on the election of a knight. A complete list of knights of the Thistle, from the revival or creation of the order in 1687 to 1840, is given by Sir N. H. Nicolas in the work above cited.

THORINA. [THORINUM.]

THORINUM (Th). A metallic body discovered by Berzelius in an earth to which he had given the name of *thorina*. When this was converted into chloride of thorinum, and treated with potassium, after washing the mass a heavy metallic powder was left of a deep leaden-gray colour, which, when pressed in an agate mortar, acquired an iron-gray tint and a metallic lustre. It is not oxidised by water, either hot or cold, but when heated in the air it burns brilliantly, and is converted into oxide of thorium, or thorina, which is perfectly white, and devoid of any trace of fusion. Thorinum is scarcely at all acted upon by nitric acid, and slowly by the sulphuric; but hydrochloric acid dissolves it readily with the evolution of hydrogen gas. Its equivalent is 39·5.

Oxygen and Thorinum combine to form oxide of thorinum, (ThO) or thorina, by heating the metal in the air, or by decomposing the chloride by means of an alkali. When it has been strongly heated, its density is 9·402, and it is then insoluble in any acid but the sulphuric, and in that with difficulty. It is precipitated in the state of hydrate from its solutions by the alkalies, and in this state it is readily soluble in acids, and is converted into carbonate by exposure to the air. The alkaline carbonates dissolve the hydrate, carbonate, and subsalts of thorina; thorina is precipitated from solution by the ferrocyanide of potassium.

Besides combining readily with oxygen, as already mentioned, thorinum unites energetically with chlorine, sulphur, and phosphorus; but the compounds which they form have not been minutely examined.

THOROUGH-BASE, the art of playing (on keyed instruments, and according to the rules of harmony) an accompaniment from figures representing chords, such figures being placed either over or under the notes of the instrumental base staff. This is one of the many absurd terms employed in music, and its meaning is altogether arbitrary.

The figures used in *Thorough-Base* are the nine units. These represent certain intervals or sounds. Thus a 6 placed over a C in the base, points out A as an accompaniment: and that figure also implies two other notes attendant on it, namely, the 3rd and 8th, which are called the *accompaniments* of the 6th. A 6 and a 5 placed under it $\binom{6}{5}$, indicate the intervals of the 6th and 5th played together; and also, as accompanying notes, the 3rd and 8th. The figures 3, 5, and 8, singly, or together, represent the perfect or common chord. But in *Thorough-Base* a base note without any figure is supposed to carry a perfect chord. The chords are, as a general rule, assigned to the right hand of the performer, and the intervals are, in most cases, counted from an octave above the figured note. This will be more clearly understood by referring to the articles ACCOMPANIMENT, CHORD, and HARMONY.

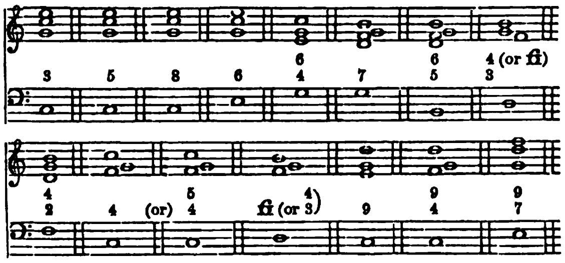
The following is a tabular view of the figures used in *Thorough-Base* to represent chords, together with those, not written, but understood, representing the accompaniments which, with the base, form the chords:—

Chords designated by figures.		Accompanying intervals.
3rd,	accompanied by a . .	5th and 8th.
5th,	„ . . .	3rd and 8th.
8th,	„ . .	5th and 3rd.
6th,	„ . . .	3rd and 8th.
$\genfrac{}{}{0pt}{}{6}{4}$th,	„ . . .	8th.
7th,	„ . . .	3rd, 5th, and 8th.
$\genfrac{}{}{0pt}{}{6}{5}$th,	„ . . .	3rd and 8th.
$\genfrac{}{}{0pt}{}{4}{3}$rd,	„ . . .	major 6th.
$\genfrac{}{}{0pt}{}{4}{2}$nd,	„ . . .	6th.
4th.	sometimes called the 11th, accompanied by a . .	5th and 8th,

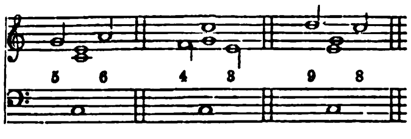
Chords designated by figures.		Accompanying intervals.
$^{5}_{4}$th,	accompanied by an . .	8th.
6̸th (sharp 6th)	,, . . .	$^{4}_{3}$rd.
9th,	,, . . .	3rd and 5th.
$^{9}_{4}$th,	,, . . .	5th,
$^{9}_{7}$th,	,, . . .	3rd.
7̸ (sharp 7th)	,, . . .	5th, 4th, and 2nd.

Some other chords of an extraordinary kind are occasionally formed; but they are always clearly denoted, in *Thorough-Base*, by an ample number of figures.

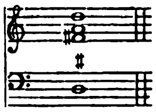
The above chords exemplified.



When two figures are placed in succession over one base note, the time of the latter is divided between them. Example :—



A sharp, or flat, or natural, placed alone over a base note, relates solely to the 3rd. Example :—



When other intervals are to be raised or lowered, the proper characters for the purpose are prefixed to them. A dash through a figure is equivalent to a sharp.

The practice of figuring a base staff, whether in a score or in the part assigned to a keyed instrument, has fallen into disuse, the harmony being now fully and clearly presented to the eye of the accompanyist in notes placed in a treble staff over the base. But a knowledge of what is yet too commonly misnamed *Thorough-base*, that is to say, harmony, is absolutely indispensable to the good musician, and very much abbreviates the labour of those who, as amateurs, only aspire to a practical skill either as vocal or instrumental performers. The rules of harmony stand in the same relation to music as those of grammar do to language.

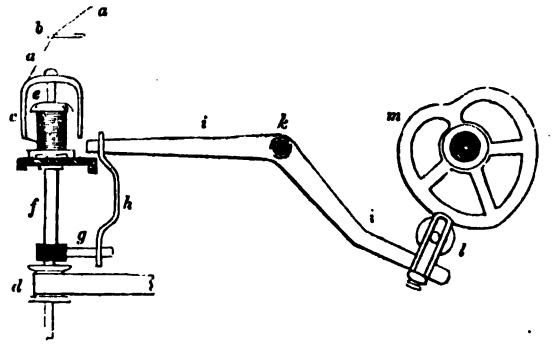
The invention of a *Figured Base* (*Basso Cifrato*, as the Italians so well denominate it) has been stated to have taken place in 1605, and is commonly attributed to Ludovico Viadana, *Maestro di Cappella* at the cathedral of Mantua. But this kind of musical abbreviation was earlier practised, and by an English composer, Richard Deering, who, in 1597, published his *Cantiones Sacræ*, at Antwerp, in which a figured base appears. And we have now before us Jacopo Peri's serious opera *Euridice*, printed at Florence in 1600, in which the base is figured throughout. Lying by us also is Caccini's *Nuove Musiche*, likewise printed at Florence, but one year later, and here we find the base regularly figured.

THREAD AND YARN. The distinction between thread and yarn is such as to render it desirable to describe them together under the present heading.

Yarn is the general name given to the threads which are woven into the various kinds of textile fabrics, whether cotton, silk, flax, hemp, wool, or worsted; the terms *twist*, *mule-weft*, *organzine*, *tram*, *abb*, *line*, &c., being particular names applied to particular sorts. Yarn for *cotton*-weaving is of two distinct kinds, according as it is intended for *warp* or *weft*; each kind being varied to suit different fabrics. *Water-twist* or *throstle-yarn* (the first name having been derived from the water-frame by which this kind of yarn was formerly spun, and the second from the throstle now employed) is smooth and wiry, and is usually employed for warp in heavy goods, such as fustians, corduroys, or for making sewing-thread. *Mule-yarn* (named from the mule machine by which it is spun) is of a soft and downy nature, calculated for the weft in coarse goods, and for both warp and weft in finer fabrics. The spun yarn is distinguished by certain numerals, which indicate the number of hanks contained in one pound, each hank consisting of 840 yards of yarn. The two kinds of machines are adapted for different numbers; thus, the *throstle* is not now often employed for yarns finer than No. 30 or 40, the higher numbers being generally spun by the *mule*. By successive improvements in the machinery employed, yarn is now spun to an exquisite degree of fineness, several hundred miles of yarn being spun from one pound of cotton. The excellence and cheapness of the yarn spun by modern machinery has led to very large exports. *Flax*-yarn is not estimated by No., like cotton, but by terms peculiar to that branch of spinning. Three hundred yards form a *lea* of flax-yarn; 38 leas form a *spindle*; 6 leas form a *rand*; 72 leas, or 21,600 yards, or 12 rands, form a *dozen*. There is this difference, however: in Scotland, flax yarn is designated by the number of lbs. in 48 leas; thus the same yarn is known in England as No. 48, and in Scotland as 1 lb. yarn. In the process of preparation by spinning, the flax becomes separated into two qualities, the finer obtaining the name of *line*, and the coarser that of *tow*; and the yarn spun from these two qualities is applied to different purposes. Modern improvements have led to the production of such fine qualities of line, that it is now used in combination with silk in pocket handkerchiefs and other fabrics. With regard to *hemp*, besides the yarn employed for weaving into sacking and other coarse goods, the term yarn is applied in rope-making in a different sense. The yarn in this case is a loose kind of string or cord, and it receives a No. according to the number of such strings required in making ropes three inches in circumference; thus, Nos. 18, 20, or 25 imply such thicknesses of yarn that 18, 20, or 25 of them are required in making a rope of the dimensions just stated. *Silk*-yarn has names applied to it not known in the examples just given. The silk is imported as a fine filament, or in the state of *raw* silk; it is twisted as a means of giving it greater firmness of texture, and then obtains the name of *singles*; two filaments are twisted together rather loosely, and formed into a yarn called *tram*, which commonly forms the weft or cross-threads of manufactured goods; lastly, two or more filaments are twisted separately into hard *singles*, and then twisted together in an opposite direction, forming a strong silken yarn called *organzine*, used generally for warp. Silk-yarn in the form of tram or organzine, that is, ready for the weaver, is called *thrown* silk. Yarn made from *wool* is called *woollen* or *worsted*, according as it is formed from short or from long wool, from clothing or from combing wool. The former of these is so spun that the elementary fibres shall be in a fit state for felting or fulling; while the latter has the filaments ranged more nearly parallel. The worsted yarns are further divided into the coarse and the fine, according as they are to be used for hosiery or for such goods as mousseline-de-laines, fine merinoes, &c.

Thread is a stronger kind of yarn. Whether or not it is composed of a greater number of filaments, it is twisted more closely, and has a harder and smoother surface. Most of it is used in needlework, as *sewing-thread*; but some is employed in net and lace making, and in other ways, though seldom in actual weaving. The manufacture of thread was first attempted in this country by Mrs. Millar, of Balgarran, in 1722, on having received some information and machinery from Holland. Her example was speedily followed by several families in Paisley, where the manufacture soon became of considerable importance. The first manufacturers imitated the kind called Nuns' or ounce thread, which was made up in hanks of forty threads each, reeled upon reels a yard in circumference; but when the profits of the manufacture were diminished by competition, it was injured by the surreptitious practices of some of the manufacturers. It was even deemed necessary, in 1788, to pass an act of parliament requiring all manufacturers of thread to use uniform standard reels of thirty-six inches in circumference, and to put thirty threads or rounds of the reel in each hank.

The manufacture of thread from fibres of cotton-wool, for sewing and other purposes, is one of the many important departments of British industry called into exercise by the improvements effected by Arkwright and his successors in spinning-machinery. The operation of combining yarns of cotton or linen into thread is performed by a machine called a doubling and twisting frame, somewhat resembling the throstle of the cotton-spinner. Along the centre of the machine is an elevated creel or frame-work, which supports two parallel rows of cops or bobbins of yarn. The cops are placed vertically, or nearly so, and the lower ends of their axes rest in oiled steps or hollows, while the upper ends are supported by wire eyes, so that they may revolve with facility. The number of cops is twice as great as that of the twisting spindles when the thread is to consist of two yarns, three times as great for thread formed of three yarns, &c. The yarn with which they are charged is frequently *gassed*, or passed quickly through a series of gas flames, to singe off any loose downy fibres. From the cops the yarns are conducted over horizontal glass rods, which are fixed parallel with the creel, and thence downwards into troughs filled with water or very thin starch-paste. To ensure the equal moistening of the yarns they are, while being drawn through the troughs, made to pass either under a glass rod, or through eyes. After being wetted the yarns pass over the rounded edge of the trough, which is covered with flannel for the purpose of absorbing the superfluous moisture; and thence under and partly around an iron roller, which is made to revolve with any required velocity by a train of wheel-work. Upon this roller rests another, of box-wood, which revolves solely by contact with the iron roller, its axis playing in vertical slots. In passing under the iron roller, then between it and the wooden roller, and finally over the latter, the yarns required to form the thread are brought together and slightly compressed; but although thus prepared for a more intimate union, they are not yet twisted together. In the annexed figure *a a* represents the united yarns which are to form the thread, and *b* is a fixed eylet through which they are conducted to the flyer *c*, which is mounted upon and revolves with a long vertical spindle set in motion by a whorl or pulley and strap at *d*. *e* is the bobbin upon which the finished thread is wound by the revolution of the flyer, which also gives to it any predetermined degree of twist. The spindle passes freely through a hole in the centre of this bobbin, which rests upon a bar called the copping-rail, the transverse section of which is indicated by a tint in the cut; and the copping-rail, which extends the whole width of the machine, is supported at intervals by vertical rods, one of which is shown at *f*. To these rods, and consequently to the copping-rail and bobbins supported by them, a reciprocating vertical motion is imparted through the connecting pieces *g* and *h*, from the bent lever *i i*, which is pivoted at *k*, and receives its motion through the adjustable friction-roller *l*, from an eccentric or heart wheel *m*. Thus by the combined rotatory motion of the spindle and flyer, and the rising and falling motion of the bobbin, the thread is at once twisted and wound regularly upon the bobbins, which may be easily removed when full. By changes in the relative sizes of some of the toothed wheels by which the moving-power is distributed from the main shaft, the spindles, which always revolve much faster than the rollers, may be made to do so to any required degree, so as to impart a greater or less degree of twist to the thread.



These few illustrations will suffice to show the nature of the twisting processes, aided by details given in such articles as Cotton; Linen; Silk; Spinning; and Woollens. We may, however, mention that the *polishing* of sewing thread is a process on which its saleable quality much depends. Mr. Adam, of Paisley, polishes sewing thread by passing it through a dressing composition, over a guide roller, through the teeth of a reed, over a metal drum, under a brush roller, again through a reed, and finally under a polishing roller covered with cloth. Mr. Brooks, of Derby, has invented a mode of producing a polish on thread, which he called *patent glacé*; and the assumption of the name *glacé thread* by Mr. Evans, of Huddersfield, led to litigation between the two inventors. The polishing of sewing thread has indeed led to more than one appeal to the law. Mr. Ewen patented a process whereby he dips a hank of thread into size, squeezes it, passes it over two rollers rapidly revolving, and applies it against a cylinder-brush, which removes all asperities. Mr. Liddell, another inventor, used two sets of rollers instead of one, and teasles instead of brushes; but in some other respects he was considered to have infringed Ewen's patent. Other appeals to the law have been made in reference to the *length* of thread wound upon a reel. A manufacturer of *Persian thread* put labels on his reels, denoting the quantities to be 100, 200, or 300 yards; whereas the real lengths were less. This was done at the request of Manchester firms which had lax notions of honesty. The manufacturer refused to continue this system; whereupon a Manchester man pirated his trade-mark, and used it for short-measure cotton thread obtained elsewhere—thus committing a double fraud.

The exports of yarn and thread have now reached an enormous quantity. In 1860 there were exported:—

	Quantity.		Declared Value.
Cotton yarn . . .	197,364,947	lbs.	£9,875,073
Cotton thread . . .	6,266,724	„	740,876
Linen yarn . . .	31,152,026	„	1,800,927
Linen thread . . .	3,230,377	„	339,236
Silk, thrown . . .	435,212	„	529,413
Silk, twist and yarn . .	456,661	„	294,878
Woollen } yarn Worsted } . .	27,533,958	„	3,843,396
Total	266,439,905	lbs.	£17,428,799

THREAD-GILDING. [Gold Lace Manufacture.]

THREATS AND THREATENING LETTERS. Threats of personal violence, or any other threats by which a man of ordinary firmness and prudence may be put in fear, and by means of which money or other property is extorted from him, amount in law to the crime of robbery. [Robbery.] And by the statute 7 Will. IV. & 1 Vict. c. 87, sect. 7, a person demanding by menaces any property of another with intent to steal the same, is declared to be guilty of felony, and is liable to imprisonment for any term not exceeding three years. It is also a misdemeanor at common law to threaten another in order to deter him from doing some lawful act, or to compel him to do an unlawful one, or to extort money or goods from him, or to obtain any other benefit to the person who makes the threat.

The offence of sending or delivering letters or writings, threatening to kill or injure the person to whom they are sent or delivered, or to burn his house, or to accuse him of some heinous crime for the purpose of extorting money, was formerly considered to be high treason (stat. 8 Hen. V. c. 6); and under the stat. 9 Geo. I. c. 22, continued for more than a century to be punishable as a capital felony. By the statutes 4 Geo. IV. c. 54, s. 3, & 10 & 11 Vict. c. 66, s. 6, a less punishment is substituted; and any person sending or delivering any writing, with or without any name or signature subscribed thereto, or with a fictitious name or signature, threatening to kill or murder any person, or to burn or destroy his house, out-house, barns, or stacks of corn or grain, hay or straw, is declared guilty of felony; this offence being now punishable with penal servitude for life, or not less than three years, or imprisonment for any term not exceeding four years. By statute 7 & 8 Geo. IV. c 29, s. 8, any person sending or delivering any letter or writing, demanding of any person with menaces, and without any reasonable or probable cause, any chattel, money, or valuable security; or accusing or threatening to accuse, or sending or delivering any letter or writing accusing or threatening to accuse, any person of any crime punishable by law with death, transportation, or pillory, or of any assault with intent to commit any rape, or of any infamous crime (the meaning of which term is defined), with a view or intent to extort or gain from such person any chattel, money, or valuable security, is declared guilty of felony; the offence being now punishable with transportation for life or not less than three years, or with imprisonment not exceeding four years, with or without whipping. Threatening to publish a libel is a misdemeanor punishable by imprisonment with or without hard labour not exceeding three years.

THREE, RULE OF, the technical name of the rule in arithmetic by which, three quantities being given, the first and second of one kind, a fourth is found such that the four are in proportion, or that the first is the same multiple part, or parts, of the second, which the third is of the fourth.

In the earliest modern treatises are found the explanatory headings of this process, from which the denomination *rule of three* has been formed by abbreviation. Almost all such abbreviations date from the time when systems of commercial arithmetic began to be written—that is, about the beginning of the 16th century. Before that time, such books as were written always contained demonstrations from full definitions; and it was not judged necessary to provide the simple case of finding a fourth proportional to three given numbers with a separate name, or to divide the rule for doing it from others. This, however, was done by traders in their daily practice, who separated the rule of three from the other parts of arithmetic, and called it the *golden rule*, an older term, probably, than *rule of three*. Bishop Tonstal, ('Ars supputandi,' 1522) begins his chapter on the "Regula de tribus notis quartum ignotum commonstrantibus" in this manner: "Præcipua omnium regula est quæ de tribus notis quartum ignotum in noticiam educentibus ab Arithmeticis traditur. Vulgus *regulam auream* vocat; quia hæc cæteris Arithmeticæ regulis velut cæteris metallis aurum præstet." Robert Recorde (1540) calls it the "feate of the rule of proportions, whiche for his excellencie is called the golden rule." Humphrey Baker (1562) uses the phrase "rule of three," and says that "the philosophers did name it the golden rule, ... but nowe in these latter daies, by us it is called the rule of three."

The immense variety of questions which are to be solved by finding a fourth proportional defies all classification; but they may all be reduced to one form, though it may in particular cases not be easy to see the mode of reduction. That form is:—A produces B; what will C produce? It may be that it is money which produces goods, or goods which produce money, or money which produces interest, or money of one country which produces money of another, or time which produces distance travelled, &c., &c., &c. The difficulty to beginners is the reduction of the question given to the above simple form, which must be done before what is (or used to be) called the *statement* of the question can be made—namely, the writing down the numbers A, B, C, in the proper order, with the marks of proportion between them:

A : B : : C : the answer required.

It is proper enough to say that this is a question of proportion when numbers only are considered, but absurd when the things represented by the numbers are used instead of the numbers. Thus, if 5 pence buy 10 apples, 7 pence will buy 14 apples, and the number 5 is to 7 as 10 is to 14, or 5 is the same fraction of 7 as 10 is of 14. But it is absurd to say that 5 pence bear the same proportion to 10 apples that

7 pence bear to 14 apples: simply because 5 pence are not any assignable fraction of 10 apples. That there is a *relation* is true; but that relation is not proportion. Thus, it is not absurd to say, in the common language of the rule, As 5 pence are to 10 apples, so are 7 pence to 14 apples; for the first does stand to the second in the same relation as the third to the fourth: 5 pence must, at all rates, do as much towards the purchase of 10 apples as 7 pence towards that of 14 apples. With this understanding, there is no objection to the common mode of statement, and the proof of the rule is as follows:—If A of the first produce B of the second, then, at the same rate of production, 1 of the first must produce $\frac{\mathrm{B}}{\mathrm{A}}$ of the second; whence C of the first must produce $\mathrm{C} \times \frac{\mathrm{B}}{\mathrm{A}}$, or $\frac{\mathrm{CB}}{\mathrm{A}}$ of the second.

The importance of the rule of three induced arithmeticians to attach two other rules to it: the inverse rule of three (called by Recorde, Baker, &c., the *backer* rule); and the double rule of three. Some of the writers of Cocker's school, apparently by an abbreviation of his words, tells us that the rule of three inverse is used "when less requires more and more requires less;" meaning that the greater the third of the given numbers, the less will be the answer, and *vice versâ*. Thus, suppose that 10*l.* has been lent me for 3 months, and I want to know how long I ought to lend a given sum (other than 10*l.*) in return: evidently the more I lend, the less the time for which I ought to lend it. If the sum be 15*l.*, then 3 months is to the time required, not as 10 to 15, but in its inverse ratio, as 15 to 10, or $15 : 10 :: 3 : 3 \times 10 \div 15$, or 2; and 2 months is the answer required.

The double rule of three (at least in the class of questions which are usually considered as falling under it) is applied where time is an element in the production which the question supposes. For example: supposing it known that A men can pave B square feet in C days, it may be asked how many men can pave b square feet in c days, or how many square feet can a men pave in c days, or how many days will it take a men to pave b square feet. If we write down the data and answer in two lines, and in the following order—force employed—effect produced—time of production—thus:

$$\begin{array}{ccc} \mathrm{A} & \mathrm{B} & \mathrm{C} \\ a & b & c \end{array}$$

the rule is—Take such an answer as will make the extremes of each line multiplied by the mean of the other, the same in both. That is, let $\mathrm{A}b\mathrm{C} = a\mathrm{B}c$, and according as a, b, or c, is to be found, the mode of working is as follows:—

$$a = \frac{\mathrm{A}b\mathrm{C}}{\mathrm{B}c}, b = \frac{a\mathrm{B}c}{\mathrm{AC}}, c = \frac{\mathrm{A}b\mathrm{C}}{a\mathrm{B}}.$$

The proof is as follows:—*One* man in C days could pave $\frac{\mathrm{B}}{\mathrm{A}}$ square feet, and in *one* day $\frac{\mathrm{B}}{\mathrm{AC}}$ square feet. By similar reasoning one man in one day could pave $\frac{b}{ac}$ square feet. Hence

$$\frac{\mathrm{B}}{\mathrm{AC}} = \frac{b}{ac}; \text{ or } a\mathrm{B}c = \mathrm{A}b\mathrm{C}.$$

The principal caution which a beginner requires is, not to suppose that the rule of three (or the rule of finding a fourth quantity which, which three others, shall constitute a proportion) is to be applied in all cases in which three quantities are given to find a fourth. That such a caution is necessary arises from the defect of works on arithmetic, which frequently exhibit this rule without any mention of proportion, and leave it to be inferred that there is but one way of obtaining a fourth quantity from three others.

THRESHING. The separation of the grain from the ear in corn has always been one of the most laborious operations on a farm. Where the quantity grown is merely sufficient to supply food for the cultivators of the soil, the simplest methods answer the purpose sufficiently. The corn, taken by handfuls, may be beaten on a piece of wood or a table, and by repeatedly turning the straw the whole of the grain may be readily beaten out. This mode of threshing may be still adopted in order to obtain the finest and ripest grains for seed; but then the straw is afterwards threshed over again with the *flail*.

Where the corn is threshed out immediately after harvest, to be put into a granary, as is the case in those countries where extensive tracts of rich land are sown with corn two or three times without much tillage or manuring, and then left to be recruited by several years' rest and pasture, the most common practice is to level a portion of a field, and, laying the corn in the straw in a large circle, to drive oxen and horses over it till it is all trodden out. This is the method alluded to in Scripture, and can only take place where the climate is serene and dry. Till ingenuity had produced machines to supersede the flail, this was the only instrument in use. The first idea of a machine for threshing was that of imitating the motion of the flail; but so much depends on the eye of the thresher, that no mechanism could well imitate the motion of his arms. The present improved threshing-machine is now so common that it will suffice to give the general principle of action. A rapid motion is given to a hollow cylinder round a horizontal axis; on the outer surface there are projecting ribs parallel to the axis at equal distances from each other; the width of these is from two to six inches. Around half the cylinder is a case, the inner surface of which is lined with plates of cast-iron grooved in the direction of the axis. The ribs or beaters come quite close to these grooves, so that an ear of wheat or other corn cannot well pass between them without being flattened. The sheaves of corn, having been untied, are spread on a slanting table, and in some machines are drawn in between two iron rollers, of which one is plain and the other fluted. The motion of these rollers is slow, while that of the cylinder or drum is rapid. The beaters act on the straw as it comes through, and beat out most of the corn; but what remains is carried in between the beaters and the fluted case, and when it has made half a revolution all the grain has been beaten and rubbed out. It falls on a shaker which lets the grain through, but tosses off the straw. Moveable threshing-machines are very generally in use in England. The price of threshing in this way is about half of what is usually paid for threshing with the flail; it is more rapidly done, there is less chance of pilfering, and fewer grains remain in the straw.

On very large farms it has been found economical to erect a steam-engine to work the threshing-machine, chaff-cutter, and other domestic implements. But travelling machines thresh out much the largest quantity of the corn that is grown in England. The moveable steam-engines which are used for working such machines are now made in immense numbers, and no doubt 15,000 to 20,000 horse-power is thus every year added to the forces used in agriculture.

THROMBUS is a tumour formed by blood effused from a vein after bleeding, and coagulated in the adjacent cellular tissue. It is a kind of intense ecchymosis or bruise, and usually arises from the puncture in the vein not having been made exactly opposite that in the skin, so that some of the blood, instead of flowing out, is infiltrated between the vein and the surface. It is rarely of sufficient importance to require treatment, and is usually removed like the effused blood of an ordinary bruise. Sometimes, however, inflammation ensues around the tumour, which should be treated by leeches and cold; or, if it proceed to suppuration, should be managed like a common abscess.

THRUSH or APHTHÆ is a disease to which young children are particularly liable. It is a disease of the mucous membrane of the mouth and fauces, and manifests itself in the form of small points, rings, conical or hemispherical elevations. These sometimes increase in size, and become large spots, which are covered with a membrane of milk or pearl-white colour passing into a gray or yellowish colour. This membranous matter is of a more or less soft consistence, and varies in thickness. It is at first firmly adherent to the mucous membrane, but eventually peels off, leaving the mucous membrane uninjured. These spots are found on the inner edge of the lips, on the cheek, the gums and the palate; on the upper and lower surface of the tongue, in the throat, and in the œsophagus down to the stomach.

On placing this membranous secretion under the microscope, it is found to consist of epithelial cells, a certain amount of exuded matter, and of *the filaments and spores of a fungus* known by the name of *Oidium albicans*. [ENTOPHYTA; OIDIUM, in NAT. HIST. DIV.]

The filaments of the fungus are cylindrical, elongated, straight, or curved and tubular. The interior of the tube is transparent. In the midst of these filaments are found minute bodies composed of two to four oval cells. These are the germinating spores from which originate the true spores; which lie together frequently in masses and vary in number according to the age of the fungus.

There is no doubt that thrush entirely depends on the presence of this fungus. It appears, however, that certain states of the system invite their attacks. When children are weakly or have been subject to derangement of the bowels from any cause, the fungus appears to find a fit nidus for its development. In some cases the irritation produced by the fungus engenders inflammation which ends in ulceration, and this may spread and even produce destructive effects.

Old people as well as children are subject to attacks of the same fungus when the conditions are present which invite their attacks. Such being the nature of thrush, it is very clear that it is not critical of any general state of the system.

Thrush is often confounded with various affections of the mouth, such as idiopathic inflammation with ulceration, accumulation of epithelial cells, the fur of the tongue, and the remains of food especially milk, from all of which it may be easily distinguished by the presence of the filaments and spores of the fungus.

In the treatment, the object should be to destroy the fungus by external application, and to rectify the diseased condition of the child. A dilute solution of nitrate of silver painted over the aphthous spots has been found useful as an external application. Acidity of the stomach and bowels may be corrected by the carbonates of potash, magnesia, or soda. The preparations of iron with cod-liver oil are amongst the best remedies for the constitutional state in which thrush occurs.

(Küchemeister *On Animal and Vegetable Parasites*, translated by Dr. Lankester.)

THUG (from Hindustanee *t'hagna*, to deceive) means a deceiver, and is the special appellation of secret murderers in India. Of their origin nothing can be said with any degree of certainty. The Thugs themselves refer it to the remotest antiquity, and there is no doubt that the ceremonies with which they carry on their murderous trade can be traced as far back as the Kâlika Purâna, where we find them described with the utmost accuracy. Their gangs, consisting of from ten to two or three hundred men of all races, castes, sects, and religions, yet all joining in the worship of Kâli, moved about all parts of India, sacrificing to their tutelary goddess every victim that they could seize, and sharing the plunder among themselves. Still they shed no blood, except when forced by circumstances; murder being their religion, the performance of its duties required secrecy, and the instrument of death was a rope or a handkerchief, which could excite no suspicion. They were stranglers. Every gang had its leader, the *Jemadar* or *Sirdar;* its teacher, the *Guru,* whose duty it was to initiate the novice into the secret of using the *roomal,* or handkerchief. Then came the *Bhuttotes,* that is, stranglers; and the *Sothas,* or entrappers; and at last the *Lughaees,* or gravediggers. In a country like India, the striking character of whose inhabitants is an almost incredible apathy, it was easy for them to commit the most outrageous murders without exciting the interest of the victim's relations. The immense jungles which border the roads afforded the Lughaees every facility for effectually concealing the bodies; and the prevailing custom of travelling in parties prevented the designs of the Sotha from being suspected, whenever he succeeded in offering the protection of his Jemadar to travellers whom their wealth induced him to entrap. The Thugs generally assumed the appearance of merchants, which increased the confidence of their victims, whom they despatched with the greatest celerity whenever they found a convenient place. Whilst the Bhuttotes arranged themselves in a manner to effect their purpose with facility, the Lughaees dug the hole; and at a given signal the noose was passed round the neck of the traveller, and, being taken unawares, he was strangled without being able to make any resistance. He was then thrown into the hole, and large incisions were made in the abdomen to prevent the corpse from swelling, and the whole was covered over with a layer of dry sand, another of thorns and bushes, and over all was thrown the earth which had been dug out, which they smoothed down so as not to attract the notice of travellers. After every murder they offered a sacrifice to Kâli, which they called *Tapounee.* It was performed in the following manner:—A large sheet was spread over the cleanest spot they could select, and on this was cast a pile consisting of one rupee and four anas' worth of coarse sugar; near this they placed the consecrated pickaxe (an instrument sacred to Siva and Bhâvanî), and a piece of silver as a *rûpa darsana,* or silver offering. The leader then sat down on the sheet, and the best stranglers placed themselves on each side of him with their faces to the west. They then distributed the sugar and ate it in solemn silence. But for this, as well as other ceremonies, we must refer to the works of Colonel Sleeman and Captain Meadows, as well as to an article in the 130th number of the 'Edinburgh Review.'

We have already observed that Thugs were found exercising their fearful trade in all parts of India. In the Deccan they were called Phânsîgars (from Sanskrit *pâsa,* a noose) or noosers, and on them we have a very interesting paper in the 13th volume of the 'Asiatic Researches.' Their customs are the same as those of the northern Thugs; but, having fewer Mohammedans among them, they are more strict observers of the duties which their religion imposes; they kill neither women, nor old men, nor any of the subjects which the Kâlika Purâna (in the 'Rudhira Adyâya') declares to be unfit for a sacrifice to Devî. In the same volume of the 'Asiatic Researches' there is another article on them, by Mr. Shakespear: both were written in 1816.

The origin of this atrocious worship is undoubtedly Hindu. The Thugs maintain that their occupation is represented in the caves of Ellora, as well as all other trades. Moreover, the terms they use are chiefly of Sanskrit origin; and the worship of Kâli, as described in the Kâlika Purâna, corresponds so well to the religious ceremonies of the Thugs, that there can be little doubt as to their identity. ('Asiatic Researches,' vol. v.) All the ceremonies of the Thugs are fixed by Purâna, the date of which it is difficult to ascertain; but frequent allusions are made to it in the Vîra Charita, a drama of Bhâvabhûti, who lived at the court of King Bhoja in the beginning of the 8th century of our era.

Thévenot, in his 'Travels' (part iii., ch. 22), is the first to notice the Thugs: he describes them as infesting the road from Agra to Delhi, and using a long rope furnished with a noose, which they throw with great dexterity round the traveller's neck; and he relates that their Sothas were frequently women. About ten years after Thévenot, Dr. Fryer found them at Surat, where a gang of them were executed. He describes them as Thévenot does; and it appears from the description that they belonged to the *Mooltaneas,* a peculiar class of Mohammedan Thugs.

Although the whole of the ceremonial is Hindu, the Thugs themselves, whether Hindu or Mohammedan, maintain that they descend from seven Mohammedan clans, Thugs, Bhys, Bursote, Kachunee, Huttar, Ganoo, and Thundee ('Ramaseeana,' p. 11); the seven clans are admitted to be the most ancient and the original stock on which all the others have been engrafted. This circumstance may lead us to suspect that Mohammedans were indeed the first to give a sort of political system to the Thugs; and the seven clans of Ismailis, whose occupation was murder as dreadful as that of the Thugs, may, when persecuted in the last days of their political existence, have joined themselves to the Hindu Phânsîgars, and, adopting their ritual, have given rise to their present institution. This point is investigated with much ingenuity in an article on the 'Secret Societies of Asia,' in the 49th vol. of 'Blackwood's Magazine.' Shah Jehan and Aurengzebe instituted criminal proceedings against them. After this we again lose sight of them until the time of Hyder Ali, who proceeded against them in a summary way. Mysore, however, seems to have been their favourite residence; for in order to suppress them, in the reign of Tippoo Sultan, many of them were apprehended and sentenced to hard labour, and others suffered mutilation. It was in Mysore also that the English government first discovered them soon after 1799; but it was not before 1810 that any measures were taken for their extermination; and a plan for their suppression, which was successful, was adopted in 1830 by the then governor-general, Lord William Bentinck.

(*Ramaseeana, or Vocabulary of the Peculiar Language used by the Thugs,* Calcutta, 1836: this work is written by Col. Sleeman; *The Confessions of a Thug,* by Captain Meadows, 1840, London.)

THUJONE. A hydrocarbon produced by the action of iodine upon the essential oil of Arbor Vitæ (*Thuja occidentalis*).

THUNDER is an explosion accompanied by a loud noise, which is heard after a discharge of lightning from the clouds. The character of the noise is variable: it sometimes resembles that which is produced when a single piece of ordnance is fired; at other times it is a rolling sound like the successive discharges of several great guns; and occasionally it may be compared to a series of sharp reports from a fire of musketry.

The identity of lightning with the electric fluid is now well known [LIGHTNING], but the physical cause of the detonation which accompanies the flash is still the subject of conjecture; in general it is considered that lightning, by its heat, creates a partial vacuum in the atmosphere, and that the sudden rushing of air into the void space produces the sound; but various reasons have been assigned for its prolongation. It was formerly supposed that the rolling noise is merely the result of several echoes caused by the sound being reflected from mountains, woods, buildings, or clouds, or from the latter alone when a thunder-storm takes place over the ocean: this opinion seems to have been founded upon the fact that the report of a fire-arm discharged in a mountainous tract is prolonged by the echoes during at least half a minute, which is about the time that the rolling of thunder continues. But though the reflections of sound are, very probably, in part, or at times, the causes of the prolongation of the report arising from the explosion, yet it must be admitted that these will not always afford a satisfactory explanation of the phenomena. It may happen, for example, that, when the sky is uniformly covered with clouds, a flash of lightning will dart from the zenith, and, after a few seconds, the crash of thunder will take place accompanied by a rolling sound: soon, a second flash may pierce the clouds in the zenith and thunder may follow, but now the crash, though loud, may not be prolonged. It is justly observed by M. Arago that this is very different from the phenomena of echoes; and the explanation which was first proposed by Dr. Hooke ('Posthumous Works,' 1705) is perhaps that which possesses the highest degree of probability. The flashes of lightning, Dr. Hooke observes, are either simple or multiple: the first occupies but one small portion of space, and gives rise to an instantaneous report; the multiple flash takes place at different parts of one long line: if these parts should be situated in a circular arc, and the observer should be in its centre, all the reports would arrive at his ear at the same time, and still one loud crash only would be heard; but if the parts were nearly in a straight line, and the observer were at one of its extremities, the reports, whether they take place at the same instant or in succession, would arrive at his ear at different times, depending wholly or partly on the distances. It may be considered therefore that the rolling arises from the circumstance that the points of explosion are at different distances from the observer; and it will follow that the duration of the noise is equal to the time in which sound travels through an interval equal to the difference between the lengths of two lines drawn from the observer to the two extremities of the flash. The flash of lightning and the report of the thunder take place in reality at the same moment; but since sound travels at the rate of 1100 feet per second, while the passage of light from the cloud to the observer may be considered as instantaneous, it follows that, on counting the number of seconds which elapse between the time of seeing the flash and hearing the report, the distance of the thunder-cloud from the observer may be ascertained if 1100 feet be multiplied by that number of seconds.

An opinion prevails that thunder has been heard when the sky was without a cloud, but the fact can scarcely be said to be satisfactorily established; for the sounds which, in countries subject to earthquakes, have been supposed to be thunder, proceed from under the ground, and may result from a different cause. Volney however relates that, being one day at Pontchartrain near Versailles, when no cloud was visible, he heard distinctly four or five claps of thunder; he adds, that about an hour afterwards the sky became overcast, and a violent hailstorm followed. On this relation M. Arago observes, that the sounds could not have been heard if they had come from clouds at a greater distance than six leagues; and if the clouds had been at, or a little within, that distance, they must have been visible, unless it be supposed that they were not more than a few yards above the ground; but the hail which followed the thunder must have proceeded from clouds having great elevation, though at the time the claps were heard they were too remote to allow any sound from them to reach the ear; and therefore he concludes that the sounds must have been produced in the air itself.

From the meteorological observations made by Dr. Scoresby, and Captains Phipps, Parry, and Ross, it appears that neither thunder nor lightning is known to take place beyond the 75th degree of north latitude; even so low as the 70th degree those phenomena are very rare: and in the tables of Captain Parry the occurrence of thunder and lightning is mentioned but once between June, 1821, and September, 1823. Captain Franklin also, in 67½° N. lat., heard thunder on one day only between September, 1825, and August, 1826.

THURSDAY. [Week.]

THYMENE ($C_{20}H_{16}$). A hydrocarbon isomeric with oil of turpentine, forming one of the constituents of the essential oil of thyme.

THYMINE. An organic base found in the *thymus gland* of the calf (sweetbread). It crystallises in needles, and also forms crystalline salts. Its composition has not been determined.

THYMÖIL. [Thymole.]

THYMOLE ($C_{20}H_{13}O, HO$). *Hydrate of thymyl.* The oxidised portion of the essential oil of thyme, forming about one-half of that essence. It crystallises in oblique rhomboidal prisms, which are nearly insoluble in water, but very soluble in alcohol and in ether. Under the influence of oxidising agents it yields a crystalline substance termed *thymöil* ($C_{24}H_{16}O_4$), which is homologous with quinone.

THYMYL-SULPHURIC ACID ($C_{20}H_{13}O, HO, S_2O_6$). An unimportant acid, obtained by the action of concentrated sulphuric acid upon *thymol.*

THYMYL-SULPHUROUS ACID. Synonymous with *Sulphocymolic acid* [Cymole].

TIA'RA (τιάρα or τιάρας), a high kind of hat, which was in ancient times worn by the inhabitants of Middle and Western Asia, especially by the Assyrians, Persians, Parthians, Armenians, and Phrygians. There were two kinds of tiaras: the upright tiara was only used by kings, priests, and other persons of the highest rank, and the upper part had frequently the shape of a crown; the tiara worn by other people was of a soft and flexible material, so that it hung down on one side, as in the case of the so-called Phrygian bonnet. (Hesychius and Suidas, *s. v.* τιάρα.) The tiaras of persons of high rank were of the most costly colours, such as purple, and adorned with gold and precious stones.

In modern times the term tiara is applied to the head-dress of the popes, which is worn on solemn occasions, and consists of a triple crown. The peculiar form of the papal tiara has led some archæologists to trace its origin back to pagan antiquity. Triple crowns bearing a marked resemblance to the papal tiara are worn by the Assyrian kings as represented on the slabs found at Nineveh by Botta and Layard.

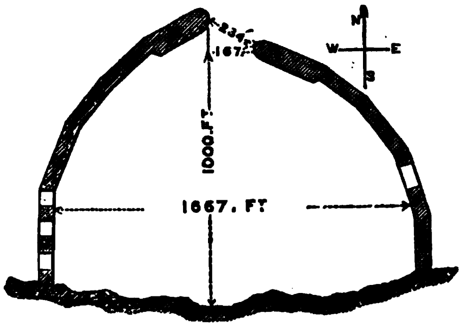
TIDAL HARBOURS. The enclosures for the protection of vessels which are situated upon the sea shore, or the portions of rivers affected by the rise of the tides, are usually known by the distinguishing name of *tidal harbours,* on account of the peculiar arrangements adopted in them in consequence of the variations of level in the waters, and of the currents which may prevail in the offing. Tidal harbours may be *floating* or *dry,* according to the rise of the tide, or the depth of water, when no artificial basins are formed; or they may be classified as *natural* or *artificial* harbours, according to the configuration of the coast, and the mode of construction adopted in them.

A natural *floating* harbour is one wherein there is at all times of the tide a sufficient depth of water to maintain a vessel afloat; a natural *dry* harbour is one which is left without water at low tides, and in which the vessels are obliged "to beach," or "to take the ground," that is to say, are left temporarily high and dry. Artificial harbours present occasionally one, or both, of these conditions; but as they are usually formed in positions where the navigation is sufficiently active to require great facilities for the commerce carried on in them, it is rare that artificial tidal harbours are constructed without the formation of floating basins in which large vessels may be kept constantly afloat. Dry tidal harbours are only of use for coasting traffic, or for vessels of small burden. The outer harbours of ports of greater importance are often in fact nothing but tidal harbours, dry at low tides; but in such cases they are accompanied by half-tide basins, and inner harbours or docks, in which the level of the water is constantly maintained at that of the high tide by means of lock gates, or pontoons. Graving docks, gridirons, scouring sluices, warehouses, and other appliances are added in such cases according to the local physical conditions of the situation, to the nature of the trade, or to the fiscal organisation of the country in which the harbours may be situated. These details have already been discussed under Docks; and they evidently must be the same in all import harbours, whether tidal, or otherwise; or whether the outer harbour be wet or dry.

Upon an open coast, like that of the southern counties of England, excepting between the Race of Portland and Selsea Point, the harbours must all be tidal, and dry at low water, unless they should be placed at the mouths of rivers, or at the head of deep inlets from the sea. Milford Haven and Plymouth are instances of this favourable natural configuration, and there is little necessity for the formation of closed docks in either of them. Southampton and Portsmouth present very great advantages also, and they are almost entirely devoid of the inconveniences usually attached to tidal harbours, for vessels can lie in the inclosed entrances to the floating basins of either of those ports without "touching," unless when their burden is very great indeed. In the case of ordinary tidal harbours, it therefore follows that, unless there should exist near them a good sheltered roadstead, vessels cannot safely "make" them, unless at high water; nor can they ever become really "harbours of refuge," which should be accessible at all times of the tide. Hâvre and Liverpool are instances of tidal harbours presenting tolerably favourable conditions of access in consequence of the existence of roadsteads. Cherbourg is an instance of a tidal harbour rendered safe by the creation of an artificial roadstead; for though the military port of Cherbourg has a sufficient depth of water to allow the largest vessels to enter at any time of the tide, yet the commercial port is left high and dry twice a day. Ramsgate, Dieppe, and the little harbour of refuge (so called) at Port en Bessin are instances of the true tidal harbours, with all their characteristics and all their inconveniences. They can only be entered at high tide; their jetties are so much exposed, that if a vessel should happen to miss the entrance she would almost infallibly be wrecked; and they are all liable to be silted up by the alluvial matters carried forward by the flood-tides on their shores. [Tidal Waters and Currents.]

Under Piers, the modes of constructing and the principles of designing the walls which inclose the spaces intended to form harbours have been already discussed; and it may, under these circumstances, suffice to say that the area to be inclosed in a tidal harbour designed to receive ordinary coasting vessels should not be less than six acres of water surface; and that the area should increase from this minimum dimension in proportion to the depth of water and to the activity of the commercial relations of the locality. In the case of tidal harbours of refuge, the area must be proportioned to the number of vessels likely to resort to them. Thus the tidal harbour of Southampton Docks, in which there is 18 feet of water at low tides, has an area of 16 acres; the area of the tidal basin of the new port of St. Nazaire, at the mouth of the Loire, is about 22½ acres; that of the tidal harbour of Port en Bessin, is about 27 acres; that of the outer harbour of Ramsgate is about 30¼ acres. Even in dry tidal harbours it is desirable that the extremities of the jetties should be carried out into 6 feet water at low neap tides; for the minimum depth of water at the entrance should never be less than 18 or 20 feet.

It may, perhaps, be advisable to state that tidal harbours whose entrances are exposed to be swept by a strong flood current should, generally speaking, have the jetty against which the flood strikes carried beyond the jetty on the opposite side; whereas in deep-water harbours the relative lengths of the jetties are regulated by their positions with respect to the direction of the prevailing wind. In fact the extension of the jetty on the outside of the flood may give rise to a local counter-current which would facilitate the entry into the harbour; and in some respects it may even cause the tide to "stale," as seamen say, or to remain for a short time at a constant height in the inclosed space, in consequence of the resistance offered by the great ebb-tide in the offing to the efflux of the small quantity of water in the port. The various currents which prevail in the British Channel, at the mouth of the Seine, and of the Southampton Water, may be referred to as illustrations of these peculiar conditions; and at Hâvre they occur in such a manner as to render the tidal outer harbour of nearly as great value as an ordinary floating harbour during two hours of each high tide, whilst at the same time they create a strong current setting into the tidal harbour during the flood, or precisely at the period when vessels are entering. Sometimes, however, these local currents give rise to bars or sand-banks, either across the mouth of the harbours or on the down side (to the flood) of the main channel, in consequence of the interferences they produce with the advance of the alluvions carried forward by the flood. Thus, at Dieppe, Boulogne, Newhaven, Harwich, Harlingen, &c., bars exist at the mouths of the tidal harbours, and they are usually of a very dangerous character, although occasionally, as at the last-named harbour in the Zuyder Zee, the bars may form natural breakwaters, inclosing shallow and imperfect



roadsteads. There are, in fact, very few positions in which tidal harbours are free from inconvenience, arising either from bars or from the advance of alluvial matters. The tidal harbour of refuge of Port en Bessin, in the department of the Calvados, presents in this respect some peculiarities to which it may be desirable to call attention, on account of the geological interest, quite as much as on account of the lessons in engineering, which they furnish. Port en Bessin is erected on a coast entirely open to the north, north-east, and north-west; the most dangerous storms blow from the north-east; and the flood-tide comes in from west by north. The jetty on the west side has been built with openings, for the avowed object of allowing the flood to sweep through the head of the harbour; and an opening is left in the eastern jetty to allow a fresh-water river, which rises from between the clay beds of the lower oolitic formations on the shore, to escape. This river would appear to be the continuation of the little river Drome, which loses itself about two miles in the interior, there passing between the formation known locally as the "argile du Port en Bessin" and the lower oolite itself, until it thus escapes on the sea-shore.

In consequence of the frequent occurrence of bars and banks at the mouths of tidal harbours, it is more than usually necessary that tidal signals, lighthouses, and fog-bells should be established upon them, and that the navigable channel should be carefully buoyed. These precautionary details must not, of course, be neglected in floating tidal harbours, if the latter should present any local peculiarities; but they are usually less necessary than in dry harbours; nor does there exist in the former the same necessity for the existence of a soft bottom, of mud or of sand, that exists in harbours wherein vessels are likely to take the ground. In floating or in ordinary tidal harbours which have docks for the reception of large vessels, the entrances to the docks must be placed at a position in the outer basin removed from the agitation of the open sea; and it would appear from the practical working of the docks at Hâvre, Liverpool, &c., that it is preferable to make the entrance to the floating dock from an exterior half-tide dock, rather than from the outer harbour itself. There is, in fact, a danger of the gates communicating with the outer harbour being occasionally forced open by the agitation of the latter; and at all times the half-tide basins facilitate greatly the manœuvres of a port. In some tidal harbours, as at Hâvre, Dieppe, Ostend, &c., pains are taken to break the waves which may be driven in from the open sea, by the erection of timber stockades and inclined floors of masonry; but in the majority of cases it is found that the waves become sufficiently stilled by the fact of their passing through a narrow passage at the entrance, and then widening out into a large sheltered area.

(Sir J. Rennie, *on Harbours; Sganzin, Cours de Construction;* Minard, *Travaux Hydrauliques à la Mer;* the Parliamentary *Reports on the Highland Roads,* &c.; Smeaton's *Reports; Life of Telford;* &c., &c. The Report of the Commission on *Tidal Harbours,* 1845, may also be consulted.)

TIDAL WATERS AND CURRENTS. The partial streams of water set in motion by the great tidal waves, which frequently flow in directions different from, or even directly opposed to, the advance of the great tide waves themselves, are known technically by the name of *tidal currents;* and they are of the greatest importance in all nautical, or hydraulic, engineering operations, on account of the interference they are able to produce in the conditions of access to harbours on the sea-coast, or to the embouchures of rivers. These currents are produced either by the projection of head-lands, or by the retarding influence of the sea-shore upon the advance of a portion of the tide wave, and they are therefore subject to so many modifying conditions, as to render it more easy to explain their nature by reference to some of the most remarkable currents known to exist. A few illustrations of them will therefore be given; but before so doing, it may be desirable to observe that the great oceanic currents, such as the Gulf stream, the current through the straits of Gibraltar and at the head of the Mediterranean, &c., have no connection with the class of phenomena in question; for their creation and propagation depend upon cosmical causes of a very different and of a much more complicated nature than those which produce the real tidal currents of the sea shores.

Now, the great flood tide, following the impulsion it receives from the attraction of the sun and the moon, and from the rotation of the earth, advances normally from the west towards the east; and in mid-ocean the only tidal current is precisely in this uniform direction. On approaching the shores of a large island, or of a continent, however, the tide striking the advanced headlands is diverted from its course in some cases, whilst in others, the great advancing stream may be carried in its former direction past the portion of the coast immediately behind the headland, and thus only allow the flood tide to exhibit itself by derivation from the main stream. On the shores of the Atlantic, for instance, the flood wave striking the extremities of Ireland, England, and the department of the Finisterre in France, changes its course in a remarkable manner. A portion of the flood continues to advance in its original direction through the British Channel; a second portion runs northwards along the western coast of Ireland and of Scotland, giving off in its advance a branch, or subsidiary, current running up through the St. George's Channel, and flowing in a rather north-easterly direction until it meets a smaller derived current, flowing through the Mull of Cantire, from the N.W. to the S.E.; a third portion striking Cape Finisterre turns towards the south, and runs along the coast of the Bay of Biscay. The flood tide running up the British Channel passes through the straits of Dover, and spreads itself over the North Sea, meeting a portion of the flood which had passed round the extremity of Scotland, and down the eastern coast of England, near the embouchure of the Thames; so that the united tides flow up the river, sometimes synchronously, sometimes at slight intervals. In the former case, the tide in the Thames is a simple one; in the latter it may present the peculiarity of a double rise in the level of the water; and the same phenomenon of the existence of more than one period of flood may be perceived in other rivers of the east, and even of the south, coasts of England, as well as on the northern coast of France, in consequence of the creation of subsidiary tidal currents by advancing headlands.

Thus, the Bill of Portland projects so much into the line of advance of the flood tide that the latter sweeps along in the offing at an elevation above the water in-shore, until it reaches the Needles point in its course parting with some of its own body, by derivation, into the sheltered bay. At the Needles the flood divides, one portion flowing from the W. by S. into the Southampton Water, the other continuing up the Channel, but as it passes the Spithead Passage it gives off a branch current, which flows through that channel from S.E. to N.W. until it meets the ebbing tide from the Southampton Water already running out. The Spithead flood current drives back the Southampton ebb, and thus makes the peculiar double tide of that river; and it also superposes itself in a manner upon the ebb of the coast lying west of Calshot Point so as to create a double tide, known locally by the name of the *Gulder,* which only ceases to be felt at the Bill of Portland. Very much the same kind of action may be observed on the French coast between the rocks of the Calvados and the Cape Antifer; for the first flood tidal current in the bays at the mouths of the Orne and of the Seine, derived from the edges of the great flood tide in the offing, is maintained for a variable period, by the return of a subsidiary tidal current deflected by the projection of the cape. At Southampton, the double tide keeps the water at nearly a constant height for the space of two hours; at Havre it remains in this state for about one hour and a quarter; whilst at the mouth of the Orne, the flood tide is held up for about one hour. The advantage thus produced to the navigation of those localities by these peculiar tidal currents is enormous.

The tidal current at Havre is, moreover, accompanied by a further peculiarity. As was before said, the main flood tide in the Channel runs in the offing with a direction from W. to E. until it strikes Cape Antifer; there it divides, one portion or tidal current continuing to flow up the Channel, the other running into the bay of the Seine from E. to W., until it strikes the jetty at the entrance to the port, which deflects it a little, and causes the bulk of the current to run on until it meets the Cape du Hoc. A portion of the flood is there deflected, and turns back towards the mouth of the harbour, with a general S.E. by S. direction. A ship making this port at the flood tide, has thus to encounter no less than three tidal currents, flowing in different directions; and as all the shores swept by these currents are composed of rocks consisting of materials easily transportable by the water, there is a constant formation of shifting banks at the mouths of the Seine taking place at a short distance from the shore.

The effect of tidal currents upon the outline of a coast is one of the most important forms of their action. For instance, it will be found that all the bays exposed to the action of strongly defined floods open towards their line of advance; and it also generally is the case that the most violent storms blow in the same direction, that is to say, in the direction of the flood tide. In fact, the water is driven with the most violence upon the shores by the flood tides; and they are the great agents in removing and transporting the materials detached from the shores. In all works for coast defences it is important, therefore, to calculate all the existing, and the probable future, effects of the tidal currents, observing always that they may depend in many cases on modifications of the outline of the coast lying far away from the locality considered. The advance of the flood tide on the eastern shores of England from the north to south is, for instance, an effect of the same circumstances which cause the flood tide on the west coast of Ireland, and of Scotland, to flow from south to north; and in the British Channel from west to east. The direction of the bars at the mouths of rivers pouring into seas exposed to be crossed by tidal currents, it may be added, follow as a general rule the direction of a resultant between the lines of flow of the ebb from the river, and of the advancing flood.

The greatest amount of theoretical information on the subject of the laws of hydrodynamics affecting tidal currents, is to be found in Venturoli, 'Sur la communication latérale du mouvement dans l'eau;' in Brémontier and Emmy, 'Sur les Ondes;' in Sganzin and Minard, 'Cours de Construction;' in the 'Nautical Magazine;' in Lubbock, Whewell, Airy, &c., 'On Tides,' in the 'Philosophical Transactions;' in Rennel's 'Investigation of Currents;' Young 'On Tides,' in 'Encyclopædia Britannica,' &c., &c.

TIDE MILL. A mill driven by the water which is affected by the rise and fall of the tides is called a *tide mill,* whether the wheel be affixed to a building on the land, or to a vessel floating in the river. In the former case the water sometimes acts upon an undershot wheel in escaping from a reservoir, which has been filled during the flood tide; but the working of the mill in this case can only take place when there is a sufficient difference of level above, and below, the wheel, to produce the necessary head, and the sluices must be arranged in such a manner as to regulate the dynamical effort exercised upon the wheel during the period of working, which is usually about four hours in each ebb. At other times, the motion is given by a species of horizontal reaction wheel, made to revolve horizontally by the advancing or receding tide; in this case also the action of the wheel cannot take place continuously, for at the turn of the tide in either direction there is a period during which it neither advances nor recedes; but directly the current assumes a marked velocity, either of ebb or flow, the wheel will be set in motion, in alternate directions. As the velocity of the tidal current is always greatest about the half tides, it is necessary to provide some regulating machinery for the working parts of the mill, if they should happen to be of a nature to require uniformity of motion; this remark of course applies to both the undershot, and to the horizontal wheel.

The tidal wheels attached to boats on rivers are, in fact, vertical float wheels working in unlimited water; that is to say, the stream alone acts upon the wheel by its horizontal velocity, without being in any way confined or directed by a race or channel. These wheels rarely exceed from 12 to 17 feet in diameter, and the floats vary from 12 to 24 in number; the depth of the floats never exceeds 0·25 of the radius, but is usually only about 0·20 of that dimension, and the whole of the floats are immerged; the width of the face of these wheels varies between 8 and 18 feet. In tidal rivers, where the current alternates in its direction, the floats are placed upon the radii of the wheel; though the wheels working in unlimited water, flowing in one direction, are found to produce a greater useful effect when they are made with floats inclined to the line of flow. Boat mills of this description, it may be added, should never be tolerated on rivers capable of receiving an active navigation; and under all circumstances their action is irregular, and of very little practical value. Their working effect may be represented by the formula $Pw = 20\,SV^2$: in which Pw = the effective power transmitted by the working shaft; S = the sectional area of the float; V= the velocity of the current. The working effect of the other descriptions of tidal wheels is to be calculated upon the ordinary principles applied to that class of machinery, when the head of water and the velocity of the current are known. [Water Wheel.]

(Consult D'Aubuisson, *Hydraulique*; Fabre, *Essai sur la construction des Roues Hydrauliques*; Navier, *Architecture Hydraulique*; Bossut, *Recherches expérimentales sur l'Eau et le Vent, &c.*; Gregory, *Treatise on Mechanics*.)

TIDES. [Acceleration and Retardation of Tides; Wave.]

TILES AND PAVEMENTS. A tile is a kind of thin brick, or plate of baked clay, used chiefly for covering roofs, but occasionally for paving floors, constructing drains, &c. The English name, and those by which tiles are known in other European languages, are derived from the Latin *tegula*, which contains the same element as *tego*, to cover.

Among the Greeks and Romans roofing-tiles were originally made, like bricks, of baked clay; but later, tiles of marble were made of much larger dimensions than was practicable in clay, and consequently the effect produced by their parallel joints might be brought into harmony with the rest of the building. A still more expensive and magnificent method of roofing occasionally adopted consisted in the use of tiles made of bronze and gilt. Tiles were originally made flat, or with nothing more than the hook or nozzle underneath the upper border, which fulfilled the purpose of fixing them upon the rafters. They were subsequently formed with a raised border along each side, on the upper surface, and the sides of the tile were made to converge towards the lower end, in order that the raised sides or ledges might not prevent the successive rows of tiles from overlapping each other neatly. The lines of junction between the flat tiles were covered by small semi-cylindrical tiles, called *imbrices*, the rows of which, extending from the ridge to the gutter, divided the surface of the roof into a series of channels, along which water descended to the gutter. Both the *tegulæ* and the *imbrices* terminated at the edge of the roof in ornamental pieces. Another kind of ancient tiling, mentioned by Pliny under the name of *pavonaceum*, consisted of tiles of a semicircular form at their lower edges, which, when laid in overlapping rows, somewhat resembled the feathers in the train of a peacock.

The process of making tiles is so similar to that of brick-making [Brick], that it will be sufficient to observe that only the best qualities of brick-earth are fit for the purpose. Since the year 1833 no excise-duty has been levied upon the manufacture of tiles. The roofing-tiles used in this country are chiefly of two sorts: namely, *plane-tiles*, which are flat, of a rectangular form, and usually about 10½ inches long, 6 inches wide, and 5-8ths of an inch thick; and *pan-tiles*, which also have a rectangular outline, but are bent in such a manner that, when laid on the roof, the greater part of their surface forms a concave channel for the descent of water, while one side forms a narrow convex ridge which overlaps the edge of the adjoining tile. These are usually 13½ or 14½ inches long, and about 9 inches wide, measured in a straight line from side to side. *Plane-tiles* are made with a hole near their upper extremity to receive a wooden peg, by which they are hung upon the laths of the roof. They are laid either with or without mortar, in such a manner that the successive rows overlap each other about 6 inches. *Pan-tiles* have no holes, but are hung upon the laths by ledges formed at their upper edges; they do not require so great an over-lap as plane-tiles. Tiles of a semi-cylindrical form, laid in mortar, are for covering ridges if the convex side be uppermost, and for covering gutters if the concave.

Paving-tiles are usually square, and of greater thickness than those for roofing. *Drain-tiles* are commonly made in the form of an arch, and are laid or bedded upon flat tiles, called *soles*. The substitution of *drain-pipes* for *drain-tiles* is noticed under Drainage. Machinery is now extensively employed in the manufacture of tiles, similar in principle to the brick-making machinery noticed under Brick.

What are called *Encaustic Tiles*, are productions midway in constitution between pottery and brick, and midway in artistic character between mosaic and plane-tiles [Mosaic; Tessera]. Decorative paving-tiles of baked pottery were much used in the middle ages; but their manufacture in England was almost forgotten until the late Mr. Minton revived it. The Temple Church, in London, was one of the first buildings in which the revival was exhibited; and since that period (about twenty years ago) the use of such tiles, principally for pavements, has extended largely. *Pressure* is brought to bear in their making, thereby rendering them much harder and less porous than ordinary tiles. One mode of making them is as follows: Supposing each square tile to exhibit a yellow device on a brown ground, the brown portion is formed of a suitable kind of stiff clay, pressed in a mould to a thickness of about one inch. The mould not only gives the form, but also produces depressions about a quarter of an inch deep, marking out the device. Heavy pressure is employed to harden the clay, and to give sharpness to the device. The yellow clay to fill up the depressions is mixed to the consistence of honey, and is applied chiefly by means of a kind of trowel. The clays are selected with much care, in order that they may shrink equally in drying; and they are allowed a long time to dry in the open air, before being baked. The surface is well scraped and cleaned before firing. The tiles are either left dead, or are glazed in the same manner as pottery and earthenware. If more than two colours are exhibited, the process is necessarily more complicated. To form a pavement, the tiles are usually imbedded in cement, and are roughened or in some way hollowed on the under surface to increase the hold.

Many other modes have been partially adopted for the production of ornamental paving-tiles. Mr. C. Wyatt at one time made pavements of stone inlaid in coloured cements. Other inventors substituted pieces of terra-cotta for the stone. Mr. Blashfield has tried cements coloured with metallic oxides, and bitumen coloured in like manner. Messrs. Singer and Pether have made pavements, by rolling out prepared clay into sheets, cutting it into small cubes, combining these cubes according to their colours, forming them into a slab having a defined pattern, and laying down the slab as a pavement; the cubes on this plan are usually about an inch square on each side, and are made into slabs about half a yard square. Cubes or tesseræ have since been made of exceeding hardness, by a process due to Mr. Prosser; he pulverises fire-clay and felspar, or flint, and subjects them while dry to intense pressure between two steel dies; the colour is introduced either by mixture with the powder, or by being thrown into the oven while baking. These cubes or tesseræ produce a pavement of exceeding hardness and durability.

TILLAGE, applied to arable land, is the stirring and preparing of the surface of the soil, so as to render it fit for the vegetation of the seeds committed to it: its object also is the destruction of noxious weeds.

The whole art of cultivation consists in tillage and manuring, and the profit of the husbandman depends on the perfection of the tillage and the economy of labour in producing the effect. A defect in tillage will cause a great deficiency in the crops in ordinary years. To ensure good crops, the soil should be in such a state that the rains and dews may readily be diffused through it, without giving it a wet appearance, or evaporating too rapidly. It requires great knowledge and experience to give any particular soil the exact portion of tillage which is suited to it. A fine garden-tilth, as it is called, is the most perfect for light soils which have been long cultivated and manured; when they can be brought to such a state that after continued rains the surface dries without forming a crust, and crumbles of its own accord, the tillage has been good; and the deeper this soil is stirred, the more it will produce: but where clay abounds in the soil, which in dry weather can be readily pulverised by crushing the dry clods, and be reduced to the finest powder, too much tillage may do more harm than good. The fine clay is soon converted into mud at the surface by the least rain, because it is not sufficiently porous to let the water through it; it dries into a hard crust, which effectually precludes the access of air, and consequently stops the vegetation of the seed. It is only by abundant manuring with organic matter, especially of animal origin, that this natural tendency in clays to cohere can be overcome; and until this is effected it is best to stir clay soils as deep as possible by means of subsoil-ploughs, but they should not be pulverised so that the water cannot run down between the lumps and clods, and especially the surface should be left in such a state of roughness that heavy rains cannot cover it with a coat of mud. The clods which are left on the surface imbibe the moisture more gradually, and in drying fall to pieces, by which the young plants are invigorated, and, as it were, moulded up. This is particularly the case in winter after a frost, as all clay-land farmers are well aware. It is very easily ascertained whether a soil will bear much tillage or not. It is only necessary to try some of it in a large pot or box; make the surface very fine by breaking the clods, then water it abundantly, and let it dry in the sun; if a crust is formed in drying, that soil will not bear too much harrowing and pulverising, and should be left in a moderately rough state after sowing or drilling the seed; but if, after it dries, the surface is loose and porous, then the finer the tillage the better the seed will vegetate. The whole depends on the ready admission of air or its exclusion. When grass-seeds are sown, the surface should be well pulverised; but this cannot be safely done if the soil is apt to run together when much rain falls soon after the seed is sown. Some plants, like beans, will force their way through a very hard surface; but small seeds are too weak to do so, and their growth is entirely stopped by the least crust on the surface. Besides the preparatory tillage of the soil before sowing the seed, there is a great advantage in the stirring of it as the plants are growing. On this depends all the merit of the row-culture for every kind of plant, especially those which have esculent roots or extensive foliage, and which are chiefly cultivated for the sustenance of cattle. The effect of deep tillage is here most remarkable. If rows of turnips or cabbages be sown at such a distance that a small plough or other stirring implement can be used between them, and the intervals be stirred more or less, and at different depths, it will be found that the deeper and more frequent the tillage, until the foliage covers the whole interval or the bulbs swell to a great size, the heavier and more abundant the produce will be. It was this which led Tull, the father of drill husbandry, to the conclusion that tillage was all that the soil required to maintain perpetual fertility. As tillage can be increased by mechanical contrivances where labourers are scarce, whereas the supply of manure must generally be limited, it follows that, as a general rule, the land should be well and deeply tilled, due attention being paid to the nature of the soil and its property of retaining or transmitting moisture. Very loose sands should not be much stirred until they are consolidated by the admixture of marl, clay, chalk, or well-rotten dung; but in all cases the manure should be mixed as intimately as possible with the soil, and as deep as the tillage has gone, not including the stirring of the subsoil; for the roots will always penetrate thus far and find the nourishment which they require. Those plants which throw out roots from the bottom of the stem, as wheat, barley, and oats, require the surface to be most pulverised and enriched to allow these roots to spread, and Mr. Smith of Lois Weedon has found that where land is clayey and contains the mineral food of plants, sufficient tillage between rows of wheat is all that is needed for constant cropping, or taking wheat after wheat annually from the same field. Under ordinary culture, however, of this crop a spring tillage is highly advantageous, which can only be given when the seed has been deposited in rows by drilling or in patches by dibbling. This last method is found to give much finer crops, from the circumstance that the hoe not only loosens the earth between the rows, but also between the different patches of the growing corn, by which the coronal roots are strengthened and the tillering of the stems so much encouraged, that it is not uncommon to see twenty, thirty, or more strong stems all bearing fine ears arising from one tuft of plants, the produce of one or more seeds, whose roots are matted together and send out fibres in every direction. The crowding of several plants does not prevent their growth, provided the fibres can spread around in a rich mellow soil, well pulverised, and admitting the air and moisture readily.

The old plough which acts on the principle of turning up a fresh portion of the soil, burying that which has for some time been at the surface, will probably always continue to be the chief implement of tillage; but other implements have been invented, which by means of wheels can be regulated so as to act at a greater or less depth. These have received the different names of scarifiers, grubbers, or cultivators, according to the fancy of the inventors. Many of these answer the purpose well, and save labour. They can be used in all directions so as to pulverise the soil to any degree. Heavy rollers are used when clods require breaking.

It would be endless to enumerate all the implements of tillage which are daily invented: some of the most useful have been already described. [Agricultural Implements; Arable Land; Plough.] It is however right that reference should be made to the use of steam-power in their employment.

Tillage by Steam-power.—Steam-power has long been used in driving threshing-machines and chaff-cutters, and other barn machinery. It is now coming rapidly into field use for cultivating the land. The moveable steam-engine on wheels is the source of power most generally adopted, being available for any purpose; and the higher powers of this engine, being best adapted for the laborious work of cultivation, are being made in increasing numbers. Probably in this way alone 10,000 horse-power, equal in its efficiency to at least 25,000 horses is being added annually to the force employed in agriculture in this country.

Steam-power is in the beginning cheaper than that of horses; it is continuous, while that of horses is necessarily intermittent; and it is more efficient, because a greater force can be more easily concentrated on a given point.

A horse, as used in agriculture, costs 5*d.* or 6*d.* per hour; a steam-engine, under agricultural circumstances, costs from 3*d.* to 4*d.* per horse-power per hour. A horse works in Scotland ten hours a day, in England eight or nine hours a day, in the field—it is forced to break off work for the maintenance of its strength: an engine works as many hours, with unremitting vigour, as the engineer may choose. It does, in some instances, work 24 hours per diem, and on some farms it is made to work as long as daylight lasts. Again, horses lose time in all field operations, owing to the dilatory process of turning on the headland: where steam-driven machinery is employed instead, this loss of time is greatly diminished. But the chief advantage of steam-power for cultivation arises from the ability by means of it to concentrate any quantity of force that may be desired. At Buscot Park, near Faringdon, ploughing was this spring (1861) done by steam-power in the stiff Oxford clay of that district, which could not have been done by any quantity of horses, because the power required demanded a team which would have trampled the ground into a harder state than that out of which any implement drawn after them could have got it; and there is ample experience to show that on this ground alone steam-cultivation is more efficient—resulting in better crops than those afforded by horse-cultivation. This is especially true in the case of clay lands, whose value will no doubt be materially increased by the efficient means now at length provided for working them.

There are two systems in general adoption of applying steam-power to the cultivation of the soil. In the one, which has been carried out by Mr. Smith, of Worlstone, the steam-engine stationed in one corner of a field gives motion alternately to one and the other of two windlasses detached from it, round which is coiled a portion of the wire-rope which is carried from one to the other round the piece of land that is being cultivated, and a grubber being fastened to this rope is thus dragged backwards and forwards on the largest straight side of the piece that is being worked: the anchors carrying pulleys at the ends of the working furrow and at all other corners in the course of the rope, are shifted as the extension of the work requires, and the grubber tears up or "smashes up" two or three feet in width at a time, of the land that is being cultivated. The common 7 or 8-horse power moveable steam-engine is well adapted to this work.

In Mr. Fowler's system the steam-engine is furnished with a single pulley lying horizontally beneath the boiler, and it pulls itself along the headland, while a travelling anchorage, namely, a truck on sharp discs for wheels, which cut into the land, pulls itself along the other headland. This anchor is provided with a similar pulley, and a rope travels round both pulleys, being kept tight by an arrangement on the framework of the ploughs, which is drawn by it alternately to and fro between the two. The pulleys hold this rope by a clip-groove, which hinders it from slipping, so that a single half-round holds it tight enough. The tilling implement thus drawn to and fro, consists of two sets of ploughs or grubbers facing one another; the one working when going from the engine, and the other working when travelling to the engine. The change from one to the other need not waste more than half a minute on the headland; and the furrow may be 400 yards long, or even longer. It will be easily seen what a small loss of time in the day is thus incurred, when compared with the usual experience of horse-culture. Mr. Fowler employs generally a 12-horse engine, and, with a four-furrow plough, gets over eight or ten acres a day, at a cost generally of not more than 5*s.* or 6*s.* an acre; whereas by the less efficient horse-cultivation, the process must cost at least 10*s.* or 12*s.* an acre.

There can be little doubt that the application of steam-power to the cultivation of the land will revolutionise agriculture on all clay soils. It will enable the farmer to dispense with probably nearly half his draught animals, and it will both cheapen the cost and increase the efficiency of all tillage operations.

TILT-HAMMER, is a large hammer worked by machinery, impelled either by a water-wheel or a steam-engine. Such hammers are extensively used in the manufacture of iron and steel, and the name *tilt-mill* is sometimes applied to the mechanism of which they form the principal feature. The various details given under Hammer; Iron; and Steel, will serve to illustrate the chief points in the construction and action of tilt-hammers.

TIMBER, PRESERVATION OF. [Timber.]

TIMBER AND TIMBER-TRADE. It is the purpose of this article to treat briefly of several matters relating to timber-trees, wood-working, and the timber-trade, and to refer to such portions of the subject as have been noticed in other articles.

Timber-Trees; Wood.—The botanical characteristics of timber-trees are given under the scientific names of the several trees in the Nat. Hist. Div. The economical uses of many of them are described in the present Division, under Ash, Beech, Birch, Elm, Fir, Oak, &c. But the characteristics of timber-trees, and of wood generally, may be rapidly glanced at in this place.

Wood is that part of a plant that exists between the pith and the bark. Amongst the various kinds of wood yielded by the different families, there are great differences of character depending on the mode and rapidity of its growth, the size of the fibres of which it is composed, and their relation to the medullary rays which pass through them, and also on the character of the secretions deposited in it. Endogens have no bark, and are generally hollow in the middle, and their wood does not permit of being worked into many shapes; but its cylindrical form affords great facility for constructing a variety of utensils, and for application to the simple wants of man in tropical climates. The stems of Exogens are solid, and the older the tree becomes the more solid is the wood. Hence a distinction is made between the centre of the wood of the trunk and its circumference, the one being called heart-wood, the other sap-wood. The heart-wood is the seat of the deposition of the peculiar secretion of the tree, and is frequently separated from the sap-wood by a distinct line. It is the secretion in the heart-wood that renders it darker, harder, and more durable than the sap-wood; and for practical purposes it is of importance to distinguish between the one and the other. There is much difference between the relative sizes of the ultimate woody fibres of which wood is composed; and the durability and tenacity of wood frequently depend on the fineness of its fibres. It is to the secretions deposited in the wood, probably more than to the fibres themselves, that wood is indebted for its varying degrees of density. Thus, although it has been ascertained that woody fibre itself has a specific gravity of about 1·50, water being 1, yet there are many woods whose specific gravity is lighter than water on account of the mode in which their fibres are arranged. The conducting power of wood in relation to heat is a matter of importance in the construction of buildings and other purposes. In some experiments performed by Delarive and De Candolle on prisms of different kinds of wood, to ascertain their power of conducting heat, they found that the direction of the fibres materially interfered with their conducting power. Thus it appeared that the obstruction to the passage of caloric was greater when the current was at right angles to the woody fibre than when it flowed longitudinally in the direction of the fibres. This difference also appeared to increase in proportion as the wood was a bad conductor of heat. The cooling power of these woods is another important point, and this is not at all in relation to their conducting power: thus fir-wood being 100, the cooling power of oak-wood is only 30·38, whilst that of beech-wood is 120·2; whereas, in conducting power, if fir-wood be taken at 100, then beech-wood is 83·19, and oak-wood 134·10. Another important point of inquiry with regard to the physical properties of wood, as to its value in building, &c., is its relation to moisture. The less the specific gravity of the wood the greater is its capacity for moisture: fir absorbs more and teak less than most other kinds of timber.

It is the peculiar resinous, gummy, oily, or other secretions, that give to the various woods their different colour, smell, and taste. The colouring matter is sometimes deposited in such abundance as to render it useful for dyeing, as seen in log-wood, red sanders-wood, and other woods used as dyes. Some woods have volatile oils deposited in them, which, being slowly given out, render them odoriferous; and this is the case with sandal-wood, rose-wood, the wood of cedar, fir, and other trees. Frequently bitter and other secretions are deposited in wood, giving it a peculiar taste, and rendering it useful in medicine. The wood of the quassia, as well as of the sassafras, are examples of this kind of use. The wood of trees frequently contains in small quantities the secretions which are deposited in other parts of the plant.

If wood be submitted to destructive distillation, it is decomposed, and the consequence is the production of acetic acid and an oil, which pass off, leaving a certain quantity of charcoal. Taking them one with another, the chief kinds of English timber yield, by the distillation of 1 lb. weight, about 7¼ ozs. of wood acid, 3¾ ozs. of charcoal, and 1¾ ozs. of oil.

The woods that are used by the cabinet-maker for furniture of a more delicate kind are called fancy-woods. The use of these has become much more general since the introduction of the art of veneering; and now that this is done by machinery, instead of by hand, many woods are used for furniture and other purposes which, on account of their scarcity, could have been formerly used only to a very limited extent. The most common of the fancy woods, and that which is used most by the cabinet-maker, is *mahogany*. Next in point of importance and use to mahogany is *rose-wood*. *King-wood* is a beautiful wood, used only for delicate articles. *Beef-wood* is a very heavy wood, of a pale red colour, and is brought from Australia in logs 9 feet long and 13 or 14 inches wide. *Tulip-wood* is brought into the market in very small pieces, not more than 4 feet long and 5 inches in diameter. It is clouded with red and yellow colours, and is used for bordering and making small articles, such as caddies and work-boxes. *Zebra-wood* is the production of a large tree, and is cheap enough to be made into tables, piano-fortes, &c. It is coloured brown on a white ground, and clouded with black. *Satin-wood* is of a brilliant yellow colour, with delicate glowing shades. It is found in the market in logs 2 feet wide and 7 or 8 feet long. *Sandal-wood* is of a light brown colour, with golden-coloured waves. *Ebony* and *iron-wood* are the names given to some very hard woods, mostly brought from India, although some of the species are found in Europe and America. *Canary-wood* has a deep yellow colour. *Purple-wood* has a purple colour, without veins. *Snake-wood* is of a deep red colour, with black shades. *Calamander-wood* is a handsome cheap wood, taking a high polish, and is brought from Ceylon. Other woods are called from the places they come from, as *Coromandel* wood, *Amboyna* wood, &c.

The practice of staining wood is sometimes had recourse to for the purpose of making the more common woods resemble in colour the fancy-woods. A method has been proposed of doing this by introducing into the tree during its growth various colouring agents, so that during the course of the ascent of the sap the colouring matter may be taken up and deposited in the woody tissue. Some of the woods thus treated have been made to assume very remarkable colours; but as the trees on which it can be practised are too soft and coarse for fine work, it is not likely that this method will at all supersede the use of the naturally beautiful fancy-woods.

Growing trees are exposed to the attacks of animals and of insects, in addition to their own natural causes of decay; and when they are used as timber they are still liable to the attacks of insects and of worms of a peculiar description. The mischief done by animals is of a comparatively simple and limited description; and may briefly be described as consisting in blows and wounds of the trunk, and in the violent disruption of the smaller boughs, thus rendering the formation of knots more frequent than might otherwise be the case. Birds are actually of service in woods, for the carnivorous birds do good by keeping down insect life. The woodpecker and nuthatch only attack the bark of trees when in search of the larvæ boring in them; rooks and crows destroy immense numbers of the larger beetles; and, in fact, nearly all the forest-feeding birds render the same service. Squirrels, bats, and other insect-devouring mammalia, play the same part in the economy of nature; so that our attention may almost exclusively be devoted to the consideration of the attacks of insects and of the boring worms.

There are three descriptions of insects which prey upon trees, which may be classified according to the parts they especially attack, namely, those which attack the leaves, those which attack the bark and the alburnum, and those which attack the heart-wood. The leaf-eaters are of countless varieties, some of them eating the upper, some the under surfaces, and others the substance of the leaves without touching the epidermis. Again, there are insects which only attack the flowers, some living upon the farina of the flowers, others on the fluids in the vessels of the flowers, and others on their leaves; whilst there are also other insects which injuriously affect growing timber by giving rise to galls or other analogous excrescences. The principal mischief caused by this description of insects consists in the interferences they produce in the flow of the sap, and in their interferences with the respiratory functions of the leaves; but fortunately their ravages are apparent, and their enemies are extremely numerous, both in the animal and the insect tribes. There are several varieties of the bark-feeders; some of them attacking exclusively the outer bark, some the inner bark, and some the alburnum. Their ravages, however, in all cases are exercised only superficially, so to speak, and they do not affect the quality of the timber in any serious manner. These insects may kill a tree, but the heart-wood will remain sound, whatever be their numbers. Such insects as the *Scolytus destructor* will, nevertheless, do more injury to a forest in a month than all the animals it may shade could do in a decade. The *Hylesimus fraxini*, the *Tomicus typographicus*, the *Bostrichus pinastri*, the *Sphinx apiformis*, the *Curculio abrestis*, and the *Curculio potatus* are almost equally mischievous; whilst the *Lymexylon* attacks both the alburnum and the heart-wood. Of the heart-wood devourers the most dangerous in our latitudes are the *Cossus ligniperda*, the *Cryptorhynchus lapathi*, the *Lucanidæ*, the *Cerambycidæ*, the *Sirex gigas*, the *Sirex duplex*, and the *Zengera esculens*; and of these, the *Cossus* and *Sirex* of our own latitudes, and the *Prionus giganteus* and the *Callidium giganteum* of tropical climates, together with the *Lymexylon*, attack the converted timber after it has been long removed from the forest.

Of the boring-worms the only varieties hitherto specially noticed are the *Teredo navalis* and the *Limnoria terebrans*; and their ravages seem to be the most dangerous when wood is exposed to them in decidedly salt water. The *Limnoria*, however, occasionally attacks timber in slightly brackish water, and it would seem that both these species of worms have an antipathy to water containing sulphuretted hydrogen, or some of the vegetable and mineral acids; for they do not attack timber driven into the sea-shore near the outlets of sewers, and they avoid timber which either contains, naturally, considerable proportions of pyroligneous acid, or has been artificially impregnated with creasote, sublimate of mercury, sulphate of copper, &c. The supposed immunity of the green-heart timber was long attributed to the existence of some such quality in it; and though it is now known that the boring-worms do attack that wood, they certainly do not destroy it with anything like the same rapidity that they destroy fir, beech, elm, or even oak. Notwithstanding the fearful nature of the ravages caused by the boring-worms, the habits of those creatures have not been thoroughly studied; and it is difficult to trace the conditions which tend the most decidedly to their multiplication. It would seem, however, that both the species are to be found in the greatest numbers in warm latitudes; that the *Teredo* prefers the sea-shores from which it can derive the carbonate of lime necessary for its growth; that the *Limnoria*, on the contrary, prefers the shores upon which the sands are charged with the decomposition of silicious rocks; and that the portions of the timber devoured by both these worms occur a little below and a little above the lines of high and low water: these worms, in fact, require both air and water. The works of Messrs. Forbes and Hanley ('History of British Mollusca'), Cailliaud ('Mémoire sur les Mollusques perforantes'), 'L'Instruction sur les bois de Marine,' published by the French Government, and a Report by a Commission of Dutch engineers and naturalists on the boring-worm, published in Amsterdam, 1860, should be consulted by all who are interested in the durability of hydraulic works, or in shipbuilding. Opinions seem to be divided as to the merits of the various schemes proposed for resisting the attacks of the worms upon timber. Some engineers recommend exclusively the use of copper sheeting, or of copper nails, over the whole exposed surfaces; whilst others recommend exclusively the use of creasote. In practice, it is found that the worms frequently make their way into timber in the intervals between the nails, and then devour the inner portions. Ten years' experience would also appear to show that when the creasote has been thoroughly injected into the heart of a piece of timber, the worms will not attack the latter. The injection of mineral salts, by Kyan's patent (mercury) or by Margery's patent (copper), does not seem to produce any permanently good effect; for they are all removed in course of time by the action of sea-water frequently renewed by the tide.

The system of injecting creasote seems also to provide an efficient protection against the ravages of the white ants, which are so incalculably numerous, and so destructive to timber in tropical latitudes. It also adds greatly to the durability of timber in damp confined positions; and resists the tendency of the timber to assume either the wet or the dry rot. The two last-named modes of decay are of the most serious importance to the solidity of the buildings into whose construction timber enters largely. They affect all kinds of timber, whether native grown or foreign; and though tolerably well understood by physiologists, and by practical men, it is too much the case that they are unattended to in the application of these materials.

DRY ROT has already been treated of. The *Wet Rot* proceeds from a chemical action in the wood itself, which may either arise from the decomposition of the sap retained in it, or from the decomposition of the vegetable tissue under the influence of confined moisture: for the albuminous parts of the sap, or of the wood, commence a putrefactive process directly they meet with the conditions of heat and moisture necessary for its development. It is therefore important that all timber should be cut at the season of the year when the trees contain least sap, and that the timber should be preserved in such positions as to allow the sap to pass away, for some considerable time before it is used in a building; this precaution is technically called *seasoning*. It is therefore the custom to fell timber during the winter and early spring months, because at those seasons the sap circulates with the least activity; or the time of the year for carrying on this description of work may be said to range between October and April. In addition however to this precaution, and to a careful seasoning, it is essential to remove all the alburnum of a tree, if it should be required for use in confined situations, for the fluids it retains ferment quite as dangerously to the durability of the timber as does the sap itself. The architect and the shipbuilder cannot be too particular in excluding sappy timber from positions where there would not exist a free circulation of air, and where there is any moisture. Sappy wood, moreover, is soft, and of a feeble power of resistance. The decomposition which takes place in timber affected by druxy, or by dead knots, is of the same character as the ordinary wet rot; that is to say, it proceeds from a chemical action in the wood.

A mode of rendering timber less combustible has been described under FIRE-PROOFING.

Working in Wood.—The cutting up of timber into beams and planks is described under SAW, SAW-MILL; and into thin layers under VENEERING. The use of timber in building-work is illustrated in such articles as CARPENTRY, HOUSE, ROOF, &c.; and the use of fine woods in CARVING and MARQUETRY. We proceed to a few manufacturing processes not hitherto described: first noticing, however, that Mr. Holtzapffel, for practical purposes, classifies woods under eighteen groups, according as they are used for ship-building, hydraulic engineering, house carpentry, machinery frame-work, rollers, teeth of wheels, foundry patterns, common turnery toys, best Tunbridge toys, hard-wood turning, common furniture, best furniture, ornamental work, elastic work, inelastic work, carving, colour and dye-woods, and scent-woods.

Timber-bending has recently occupied considerable attention. Various plans have been introduced by Meadows, Hookey, and other inventors, for this purpose, chiefly by the application of steam and pressure; but the most effective seems to be that of Mr. Blanchard, of Boston. He has established a manufactory for bending timber of various kinds and sizes, and rendering it applicable for the making of chair-backs, gig-shafts, sofa-frames, horse-hames, plough-handles, wheel-felloes, arch-pieces, staircase-rails, curved mouldings, ship-timbers, &c. Oak-timber 14 feet long and 16 inches square can be bent to a curve in one hour, and timber of 9 inches square in twenty minutes. A piece 12 feet long, 12¼ inches wide, and 7 inches thick, can be bent into a perfect and permanent semicircle. A trough is prepared, of the proper size and form for the curve; one side of which is rendered moveable. There is a lever, turning on a central axis, and a travelling table under the lever. The timber, after being steamed for some hours, is laid on a flexible band of metal placed on the travelling table, and is pressed and clamped down firmly to it. One end of the timber is next clamped to one end of the curved trough; the other end butts against a block, acted on by a screw. The action of the lever then drives or forces the timber into the trough; the two ends of the timber are connected by a tie or chord; the fourth side of the trough is then put in its proper place; and the timber, thus clamped and bound with a combination of forces, is left till cold. It is now found to have acquired a permanent set, without any rending, crippling, or loss of hardness and durability. The timber, in the first instance, is not put simply into a vessel full of steam; it is introduced into a hot closet, through which steam at low pressure passes in a continuous current.

Labour-saving expedients in the working of wood have been introduced in recent years nearly in as great variety as in the working of metals. The Americans, on account partly of the abundant supply of timber in that country, have been very successful in this direction. Mr. Molesworth, in a paper on this subject read before the Institute of Civil Engineers in 1857, said that the Americans have now in use no less than five different groups of wood-planing machines, exhibiting many varieties. In one group the plane has a reciprocating motion; in another there is a fixed cutter; in another a rotatory cutter; in a fourth, the cutter is on a vertical axis; and in the fifth a socket-plane is used. The angle of the cutter is made to vary with the quality of the wood operated on, the nature of the work, and the speed of movement. There are also machines for shaping irregular work; for tenoning, either with circular saws or tenoning-cutters; for copying or carving, by means of rotatory cutters advancing to and receding from an iron pattern; for dovetailing, by reciprocating chisels or by dovetailing cutters; for making boats' oars; for making railway keys; and for sawing, planing, boring, shaping, and jointing timber in various ways. One ingenious machine shapes the arms and legs of chairs; there are two vertical cutters revolving in opposite directions, at 1700 revolutions per minute; the pattern to which the wood is temporarily fastened is so pressed against the cutters as to guide the cut. As the cutters revolve in opposite directions, the work may be pressed against the one or the other, so as to suit the cut to the direction of the grain, without the trouble of reversing the position. In some districts, where wooden houses are made in large numbers for emigrants and backwoodsmen, the timber is cut up with great rapidity; one saw of a particular kind will cut into shape 10,000 shingle boards in a day; another will cut 60,000 or 70,000 laths in the same time; while another will plane 50 feet of flooring-boards per minute, tongue and groove them at the same time, and convey the chips and shavings to a fuel-house.

The inventions are little less varied, although the operations are on a much smaller scale, in England. The Enfield rifle stock is shaped entirely by machines, no less than a dozen different machines being employed in succession, some of the cutters of which revolve 6000 times per minute. A series of machines at Woolwich Arsenal make wooden scabbard-linings for cavalry swords; and so efficient are these, that by their aid two boys can make 500 scabbard-linings in a day. Rifle-bullets sometimes have a small box-wood plug inserted in the rear of each: there are machines at Woolwich which will cut and shape 300,000 of these plugs per day. Mr. Kinder, of Worcester, has invented and brought into use a complete series of machines for working in wood, by the use of which he can plane scantlings 6 or 7 inches square; work the edges of curved timbers on the square; form both regular and winding bevels; work oblique sections of irregular figures; cut tenons with shoulders of almost any pitch; make rebates and grooves of various kinds; box down or sink irregular surfaces in such a manner that the surface destroyed shall be reproduced at the required depth; and produce curved or straight beads and mouldings—all by making the wood move while the cutting instrument remains stationary. Mr. Wilson, of Banbury, has brought into use a curious series of machines for making broom and mop-handles, umbrella-sticks, brush-backs, and railway-pegs. Mr. Dickie, of Glasgow, has a series of machines for producing irregular forms in wood, such as boot-trees, shoe-lasts, gun-stocks, and shovel-handles, by a kind of differential action of several cutters. Other morticing, moulding, dovetailing, tenoning, planing, jointing, dowelling, rebating, and chamfering-machines have been invented in great variety, and introduced in various ways; but they need not be separately described.

The application of elaborate machines to the production of cheap articles is curiously illustrated in the manufacture of *fire-wood* and of *matches*. Terry's fire-wood machinery, introduced in 1857, performs all the operations of sawing, splitting, cutting, and binding. Rough blocks of wood slide down an inclined table; they are pressed by a drum against circular saws; they are sawn into pieces of a uniform length; the pieces slide down a shoot to the splitting-mill, and fall against a series of circular cutters, which cut them into flat slabs; the slabs slide down and are split into sticks, which fall into a moveable carriage, and are discharged down another shoot; they fall into a horizontal channel, where a piston, by the action of a lever and weight, presses together enough sticks to form one bundle; the piston drives them half through a circular opening; wire from a reel is made to pass round the middle of the bundle, where it is twisted and cut off; and finally, an incoming bundle pushes out the completed one. Thus the wood is not touched by hand throughout the operations. In the making of splints for congreves or lucifers, the wood is first cut into blocks by circular saws; and these are either separated into four-sided splints, by a series of lancet-points ranged equidistant, or into cylindrical splints by being forced through small perforations in a metal plate. The best pine plank, free from knots and irregularities, is alone fit for this purpose; cheap wood would injure the cutting apparatus, and thus would not be cheap in the end. A plank 12 feet long, 11 inches wide, and 3 inches thick, will cut up into 200,000 lucifer-match splints of ordinary size; and some firms thus cut up twenty of such planks in a day.

In an article by Mr. Charles Knight, in the 'Companion to the Almanac,' for 1861, an account is given of the curious wooden-ware manufactures of Buckinghamshire and one or two neighbouring counties. The beech, elm, and ash trees of those districts are brought into immediate and local manufacturing use. At Chesham are made bread-trenchers, butter-prints, cricket-bats and stumps, money bowls, washing bowls, malt shovels, sand shovels, butcher's trays, trundling-hoops, toy garden-rollers and garden-rakes, toy wheelbarrows, hat blocks, straw bonnet blocks, and wig blocks. The taste exhibited in these articles is of a humble kind, and very little machinery is employed in the production. Chair making is the chief trade in and around High Wycombe. The many thousand cheap but strong chairs made within the last few years for use in the Crystal Palace, St. Paul's, Westminster Abbey, and other public places came from the district in question. One contract of 6000 chairs for barracks, and another of 8000 for the Crystal Palace, are mentioned. "Wycombe," says Mr. Knight, "boasts of making a chair a minute all the year round: chairs which would not be unsightly in the handsomest sitting-room, and which can be sold at five shillings each. More costly chairs are here produced, as well as the commonest rush-bottom chair of the old cottage pattern. But the light caned chair, stained to imitate rosewood, or of the bright natural colour of the beech, and highly polished, finds a demand throughout the kingdom—a demand which might appear fabulous to those who have not reflected upon the extent to which a thriving industrious people create a national wealth which gives an impulse to every occupation, and fills every dwelling with comforts and elegancies of which our forefathers never dreamt. The wondrous cheapness of the Wycombe chair is produced by the division of labour in every manufactory; and by the competition amongst the manufacturers, in a trade where a small capital and careful organisation will soon reward the humblest enterprises." Some of the operations are conducted in factories of considerable size; while others are undertaken by workmen in all the villages round.

Timber Trade.—Several centuries ago the woods and forests of England were sufficient to supply all the timber required for the building of ships and houses, as well as for fuel. In the 16th century we begin to hear complaints of their exhaustion. An act was passed in 1531 requiring coopers to sell their barrels at fixed prices, and ordering that the exporters of beer should import clapboards sufficient to replace the barrels sent out of the country. Another act, passed in 1541, was designed to enforce certain restrictions respecting the felling of trees, and to prevent the conversion of woodlands into pasture or tillage. In 1558 an act was passed, entitled 'An Act that timber shall not be felled to make coles for the making of iron,' which prohibited the use of timber one foot square in iron-works within fourteen miles of the sea, or within the same distance of eight of the principal rivers of England, or any navigable stream having an outlet on the coast: but three southern counties, Kent, Sussex, and Surrey were exempt from the operations of the act. The design seems to have been to encourage the trade in timber fit for building, and to benefit those parts of the country which did not possess a sufficient supply. In 1592 the subject again attracted notice, and an act was passed, which, amongst other things, prohibited aliens exporting fish, unless they imported clapboards; and altogether prohibited the exportation of wine-casks. In the following century the scale of prices turned in favour of pit-coal.

During the decline in the internal supply of timber, it gradually became an article of extensive demand from other countries.' In 1830, according to a statement of Mr. Huskisson, the fir timber used in England for building purposes was nearly all brought from abroad. The proportion of timber of native production used for similar objects is not known or even guessed at. The north of Europe, especially the countries on the Baltic, and our colonies in British North America, are the great sources of supply. The timber of the north of Europe is generally of excellent quality, and much superior to that from the colonies. The inferior colonial timber was for many years forced into use by enormous differential duties, which amounted to a bonus of 1000 per cent. in some cases: that is, the one duty was ten times as much as the other. In 1787 the duty on foreign timber was only 6*s.* 8*d.* the load of fifty cubic feet, but it was raised at different times, until, in 1804, it amounted to 25*s.* In 1810 the duty was raised to 54*s.* 8*d.*; and from 1814 to 1820 it was 64*s.* 11*d.* and 65*s.* the load. The trade in colonial timber had scarcely any existence before 1803, although until 1798 it had been admitted free of duty; and the duty imposed in that year was only 3 per cent. *ad valorem*, which was changed in 1803 to a specific duty of 2*s.* the load. In consequence of the war there was a great rise in the price of European timber, Memel fir advancing from 78*s.* to 320*s.* the load. In order therefore to encourage the supply from our own colonies, North American timber was again, in 1806, admitted duty free; and from that time it was more largely used than Baltic timber. The return to a sounder principle of taxation was very slow. In 1821 the duty on European timber was reduced from 65*s.* to 55*s.* the load, and a duty of 10*s.* was imposed on colonial timber, leaving a preferential duty of 45*s.* still in operation. In the tariff of 1842 the duty on colonial timber was reduced to a merely nominal sum, namely, 1*s.* the load, and to 2*s.* on deals, and 6*d.* on lathwood; while that on foreign timber was to be gradually reduced to 30*s.* and 35*s.* on different kinds. The mode of charging the duty was at the same time improved and rendered less complex than before. The difference of duty was from 24*s.* to 30*s.* in favour of colonial timber. This difference was reduced in 1847 to 14*s.* In 1851 the differential duties ceased altogether; the duty was established at 7*s.* 6*d.* to 10*s.* per load, without respect to country. In 1860 it was reduced to 1*s.* and 2*s.* per load, or 1*s.* and 2*s.* per ton, according to the mode of measurement. It may here be remarked that timber is sold by the load, the cubic foot, the square foot, the foot run, the ton, the lb., or the number of pieces; but the greater portion is by the *load.* A load of unhewn timber is 40 cubic feet; of squared timber, 50 cubic feet; of planks, 150 to 600 square feet, for thicknesses varying from 1 to 4 inches. Of a very usual kind of plank, 12 feet long, 11 inches wide, and 3 inches thick, 18 make one load.

The imports of timber, in the fifteen years from 1844 to 1858 inclusive, ranged from 1,500,000 loads to 2,500,000 loads annually. In 1860 the quantities and classification were as follow:—

	Loads.
Foreign, unhewn timber	692,768
„ hewn timber	768,791
Colonial, unhewn timber	580,349
„ hewn timber	760,356
Total	2,802,284

TIMBER AND TIMBER-TREES. Timber-trees are those the wood of which is used for building or repairing houses. Oak, ash, and elm, of the age of twenty years and upwards, are the trees most generally included under that denomination; but there are many other kinds of trees, such as beech, cherry, aspen, willow, thorn, holly, horsechesnut, lime, yew, walnut, &c., which are, by the custom of certain parts of England, considered as timber-trees, as being those used in building. (Cruise, 'Dig.', t. 3, c. 2, ss. 6, 7.) Most of the cases upon the question as to what trees are to be considered timber, have arisen in reference to the stat. 46 Edw. III., c. 3, whereby it was enacted that great or grosse wood of the age of twenty, thirty, or forty years, or upwards, should not be titheable, but that *sylva cædua*, or underwood, should be titheable. (2 'Inst.', 642, 643; 3 'Rep.', 12.)

The timber-trees growing upon land belong to the owner of the inheritance. A tenant for life has only a qualified interest in them, in so far as they afford him shade and shelter, and a right to take the mast and fruit. If the tenant for life fells timber-trees on the land to any amount greater than he is entitled to as estovers, that is to say, the allowance of wood necessary for the reparation of houses and fences, he becomes liable to an action of waste [Waste]; and the trees, which by these or any other means, accidental or otherwise, have become severed from the land, may be seized by the owner of the inheritance, or an action may be brought by him for them. If, however, the estate of the tenant for life be without impeachment of waste, he has the full right to fell timber, and also the property in all timber-trees felled and blown down during his life.

In leases for lives, when timber is included, if the lessor fells the trees, the lessee may maintain an action of trespass against him, because the lessee, though he may not cut down the trees without being subject to an action of waste, has an interest in them for shade and shelter, and a right to take the mast and fruit, and may also lop them if they be not thereby injured. But where the trees are excepted in a lease, which is usually done, the lessee has no interest whatever in them, and the lessor may bring an action of trespass against him if he fells or damages them. The lessor has also a power, incident to the exception, of entering on the land in order to fell and take away the trees; though this power, for the sake of avoiding questions, is often expressly reserved.

The timber growing on copyhold estates is, by the general custom of most manors, the property of the lord, who may cut it down, provided he leaves a sufficient quantity for the repairs of the copyhold, which the copyholder is entitled to of common right. But the general right of the copyholder to have timber for the reparation of houses and for ploughbote and hedgebote may be restrained by custom, namely, that he shall not take it without assignment from the lord or his bailiff. A copyholder in fee may, by the particular custom of the manor, have a right to cut timber-trees growing on his copyhold, and sell them at his pleasure; and the same right may belong by custom to a copyholder for life, who is entitled to nominate his successor, as being a *quasi* copyholder in fee; but a custom that a copyholder for life may cut down timber is unreasonable and void, as being a destruction of the inheritance, and contrary to the nature of a life estate.

Ecclesiastical persons being considered in most respects as tenants for life of the lands held by them *jure ecclesiæ*, are not permitted to cut down timber except for repairs. The Court of Chancery will always interfere to prevent the owner of a particular estate joining with the person entitled to the inheritance for the time being to cut down the timber on the estate.

TIMBRE. [Acoustics.]

TIMBREL, a musical instrument of the highest antiquity; the *tympanum leve* of the Roman poets, and, in the opinion of all writers of any authority, the same, in an almost unaltered state, as that now known in every part of Europe under the names of tabor, tambourine, *tambour de Basque*, &c.

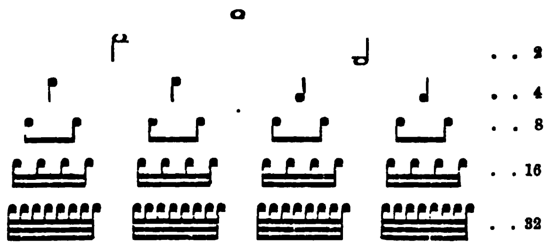
TIME (in Music) is:—

I. The measure of the duration of sound.

II. That which divides a bar into two or three equal parts, and subdivides these.

III. The movement—that is, the quickness or slowness—of a composition.

1. The degree of sound, or pitch, is shown by the place on the staff of any one of the characters called notes; but its duration is known by the particular note; that is, as minim, or crotchet, &c. The longest note, in relation to time, used in modern music, is the semibreve, which is considered the measure-note, and its average length is about four beats of a healthy man's pulse. The five other notes are proportionate parts of this. Thus the minim is in duration ½ of a semibreve; the crotchet is ¼, &c.: consequently two minims, or four crotchets, &c., are equal to one semibreve, as exhibited in the annexed table:—



2. Time is either duple or triple. The former divides every bar, or measure, into 2, or 4, &c., equal parts; the latter into 3, or 6, &c. Times are marked by the letter C,—also by this letter barred (₵), and by figures. The C, whether barred or not, indicates *Common Time*; that is, duple time, having one semibreve, or its equivalent in notes, in each bar. Figures represent the fractions of a semibreve, the upper figure the numerator, the lower the denominator. When the numerator is 2 or 4, the time is duple; when 3, it is triple; when 6 or 12, it is compound-common; and when 9, it is compound-triple. But in reality, there are only two times—binary and ternary; or duple and triple.

3. The term *Time* has hitherto had a third meaning annexed to it in musical language, by its employment in the sense of movement, a practice which has produced some confusion. The Italian word *Tempo*, signifying the same, is now growing into use. [Metronome; Rhythm.]

TIME. This word may be considered either with reference to our abstract idea of the thing signified by it, or to the measures of it which have been contrived for use in the business of life. Something on the first point of view will be found in the article Space and Time, to which the following may be added.

When we think of time in the usual manner, it is of a real thing external to ourselves, which we cannot help imagining to have an existence and a measure, both of which would remain though those who now speculate upon the conception were annihilated. A little more consideration shows that we are indebted for the idea to successions of observed events, or at least for the power of applying the idea to external objects. No description can be adequate; if we say that *change* necessarily implies *time*, and that the perception of that which *is* being different from that which *was*, suggests the notion of an interval, we see that we have already fully assumed the idea of time in the words *is* and *was*. But we may say that space and the objects which fill it exist independently of ourselves, and would undergo changes though we were not in existence to perceive them, and that therefore the times which those changes require would also exist; this involves the whole of the most abstruse part of metaphysics, and is much beyond the scope of our article. We shall therefore turn to the mode of measuring time; we have a thorough conviction that time is a magnitude, that is, has its *more* and *less*. We must ask ourselves in the first instance what we mean by a greater or a smaller time.

In the perception of time as a magnitude, that is, of intervals of time as containing more or less of duration, we refer in the first instance to a habit derived from continual acquaintance with those great natural successions on which the usual actions of our lives depend, with which we can constantly, though unconsciously, compare the duration of our thoughts and actions. There is no more an absolutely long or short time than there is an absolutely great or little space; these words are only comparative. If, for example, any one were to affirm that the universe was continually growing less and less, all its parts altering in the same proportion, and the dimensions of the human race with the rest, in such manner that the whole solar system would now go into a nut-shell, such as nut-shells were a thousand years ago, it would be impossible either for him to prove it, if true, or for any one else to prove the contradiction, if false. In like manner if any one were to say that the revolutions of all the heavenly bodies were continually accelerating, but that the properties of matter were also continually altering, and the speed with which ideas are formed and communicated, and muscular efforts made, continually increasing: it would be impossible to prove a contradiction. The oriental story is the best illustration of this:—A prince was ridiculing the legend of Mohammed being taken up by an angel, and holding many long conferences with his Creator, and having many views of heaven and hell to the smallest details, in so short a time, speaking with reference to things upon earth, that on his being brought back, the water had not quite flowed out of a jug which he had dropped from his hand when the angel caught him. A magician at the court of this prince checked his laughter by offering to prove the possibility of the story, if his highness would only dip his head into a basin of water. The prince consented, and the instant his head was immersed, found himself lying by the sea-shore in a strange country. After a reasonable quantity of malediction upon the magician, he found himself obliged by hunger to go to a neighbouring town, and seek the means of support. In time he became independent, married, and brought up a family, but was gradually stripped of all his substance by losses, and buried his wife and children. One day he threw himself into the sea to bathe, and on lifting his head out of the water, found that he had only lifted it out of the basin, the magician and the other courtiers standing round. On his bitterly reproaching the magician, the latter assured him, and was confirmed by all the bystanders, that he had done nothing but just dip his head into the basin and lift it out again. Of course the prince expressed no more doubts about the story of Mohammed, and however much any reader of the two tales may think that neither *is* true, a little reflection will show that either *might* be so. Perhaps the allegory might have been suggested by what is known to take place in dreams; there is evidence enough that many of the longest of these illusions really occupy no more than, if so much as, a second or two by the pendulum. [Dreams.]

In the laws of motion it seems as if, so to speak, matter took cognisance of time; a particle of matter will continue to describe equal spaces in *equal times*, until acted on by force from without. Yet it would be possible to state this law as follows, in such a manner as to avoid the comparison of quantities of duration. If two particles acted on by no external forces, are at A and *a* at the same epoch of duration, and at B and *b* at the same subsequent epoch, then if A C be *m* times A B, and if *a c* be *m* times *a b*, the law of motion is that C and *c* will be respectively attained at the same instant. The mathematician will readily see that the equations of motion do not depend upon the absolute recognition of time as a measurable quantity, but that any moving particle, as A, being acted on by no force, the distance A C, described in the time *t*, might be introduced into all formulæ instead of the time, without any question as to whether, time being physically considered, the space A C varies as the time. It is enough that the uninfluenced motion of any other particle should be connected with that of the standard particle by the law above described. But though we can thus avoid the idea of measurement of time, we cannot get rid of its existence or of the notion of succession of epochs; grant that we can reduce dynamics to a *theory of simultaneous positions* of particles of matter, without reference to the absolute length of time employed in passing from one position to another, there is still the notion of time in the notion of simultaneous. But, nevertheless, the idea of succession thus introduced is hardly, if at all, more physical than that which comes into most of the branches of pure mathematics, a point on which it will be worth while to dwell for a moment.

When Newton, in his doctrine of fluxions, or flowing quantities, imagined length, space, solidity, and number itself, to be generated by a continual and gradual flow, as a line by the motion of a point, a surface by that of a line, and so on, it was objected that he introduced the ideas of time and motion, both of which were foreign to pure mathematics, and properly belonged to mechanics. To get rid of these intruders, the theory of limits, which the notion of fluxions immediately requires, was attached, not to flowing quantities, but to variable quantities. Let x be a variable quantity, is one of the most common phrases of the systems which have superseded that of Newton. Now variation means change; it is never pretended that a variable has two values at once. All the difference is, that by Newton the object of consideration is supposed to grow larger or smaller, while the moderns pass in thought from a larger quantity to a smaller, or *vice versâ*, taking one first and the other afterwards. If so slight a difference as this be worth a contest, the distinction of pure and mixed science must be trivial enough: the fact is, that both systems consider successive values, and *succession is time*. If two computers were to quarrel which was the purer arithmetician, the one who stood still and counted the carriages as they passed by him, or the other who walked from one to another and counted them as they stood still, they would, to us, much resemble some of the disputants for and against the principle of fluxions.

The actual measure of time depends upon our being able to secure successions of similar events which shall furnish epochs separated by equal intervals of time. We cannot do this by our thoughts, except approximately, and for short periods. The memory of a musician, aided by the sentiment or feeling of time which is part of a good ear for music, will do remarkably well for a short period: a person who could not well preserve the division of a second into eight parts at least would make a poor figure in an orchestra. As to the judgment of considerable periods of time, it is materially influenced by the manner in which it has been spent: a time which *seems* to have been long through weariness *has* been long, and the contrary, on grounds already alluded to. Thus a year of mature age is really, to the thoughts, of a different length from one of childhood. Again, when we talk of a long period of time having passed quickly or slowly, we speak not of the time, but of our mode of remembering it. A person of rapid recapitulation always says that time has passed quickly, another of a contrary habit the contrary; and this whether the rapidity be a consequence of quickness of ideas, or of having little to recall.

In all the more correct machines which have been invented to measure time, there is but one principle: a vibration is kept up by the constant application of forces only just sufficient to counteract friction and other resistances, and machinery is applied to register the number of vibrations. The remarkable law noted under ISOCHRONISM and VIBRATION makes it comparatively immaterial whether the vibrations are of precisely the same extent. But the imperfections of such instruments, or rather, our ignorance of the precise action of disturbing causes, and particularly of changes of temperature, renders them comparatively useless for measuring long periods, so that if we could not have recourse to the motion of the heavenly bodies, there would be no permanent measure of time. And even in astronomical phenomena there is no absolute recurrence at equal intervals, though nearly enough for common purposes. The value of such phenomena for the most accurate measures consists in most of their irregularities being truly distributed about a uniform mean, so that the excesses of some periods are compensated by the defects of others, giving, in the long run, power of determining that mean with as much accuracy as our modes of measurement can appreciate. The determination of time for civil reckoning may be divided into two parts: first, the mode of making the different periods derived from the sun and moon agree with each other so as to afford an easy method of reckoning co-ordinately by both [PERIODS OF REVOLUTION]; secondly, the mode of procuring true and convenient subdivisions of the natural unit consisting of a day and night. To the second of these we now turn our attention.

The actual revolution of the earth, as measured by the time elapsed between two transits of the same star over the meridian, is called a *sidereal* day. It is divided, as are all other days, into twenty-four hours of sixty minutes each, &c. The time so given is called sidereal time. If the sun were a fixed star, this sidereal time would be the common mode of reckoning. But the sun having its own slow motion in the ecliptic, in the same direction as the revolution of the earth, the interval between one meridian transit of that body and the next is [SYNODIC] longer than the simple revolution of the earth, for just the same reason that the time in which the minute-hand of a watch moves from coincidence with the hour-hand to coincidence again is longer than the hour, or simple revolution of the minute-hand. If the sun moved uniformly, and in the equator, the real solar day, which means the interval between two meridian transits of the sun, would always be of the same length, and a little longer than the sidereal day. But the sun neither does move uniformly, nor in the equator; and each of these circumstances causes a slight irregularity in the absolute length of the solar day, or, as it is called, the *real* solar day. This is the reason why the time shown by a sundial does not agree with the watch. To remedy this inconvenience, a fictitious sun is supposed to move in the ecliptic, and uniformly, while another fictitious sun moves in the equator, also uniformly. Both the fictitious bodies have the average motion of the real sun, so that the years of the three are the same; and the fictitious sun of the ecliptic is made to coincide with the real sun at the perigee and apogee, or nearest and farthest points from the earth; while the fictitious body in the equator is made to coincide with the fictitious body of the ecliptic at the equinoxes (from which it arises that there is also a coincidence at the solstices). This fictitious sun of the equator is that to which clocks are adjusted; the interval between two of its transits, which is always of the same length, is called a *mean solar day*, which is divided into twenty-four mean solar hours, &c. The difference between time as shown by the real sun and the fictitious sun in the equator, is called the equation of time.

The determination of the equation of time is a mathematical problem of some complexity: what we have here to notice is, that owing to the joint action of the two sources of difference, it presents a very irregular series of phenomena in the course of the year. If the sun moved regularly, but in the ecliptic, there would be no equation of time at the equinoxes and solstices: if the sun moved with its elliptic irregularity, but in the equator instead of the ecliptic, there would be no equation of time at the apogee and perigee. Between the two the equation of time vanishes only when the effect of one cause of irregularity is equal and opposite to that of the other; and this takes place four times a year. In this present year (1861) the state of the equation of time is as follows:—January 1, the clock is before the sundial $3^m\ 58^s$, and continues to gain upon the dial until February 11, when there is $14^m\ 32^s$ of difference. This then begins to diminish, and continues diminishing until April 15, when the two agree, and there is no equation. The dial then is before the clock until May 14, when the equation is $3^m\ 53^s$, which diminishes until June 14, when there is again no equation. The clock is now before the dial, and the equation increases till July 26, when the equation is $6^m\ 12^s$, which diminishes until the 1st of September, when there is no equation, for the third time. The dial is now again before the clock; and by November 3, the equation has become $16^m\ 18^s$, from which time it falls off until December 24, when it is nothing for the fourth and last time. The clock then gets gradually before the dial till the end of the year. The phenomena of the next year present a repetition of the same circumstances, with some trivial variations of magnitude. There are several slight disturbing causes to which we have not thought it worth while to advert in a popular explanation: in particular, the slow motion of the solar perigee [YEAR; SUN], which will in time wholly alter the phenomena. For instance, when the perigee comes to coincide with the equinox, there will be only two periods at which the equation of time vanishes, namely, when the sun is at either equinox.

The sidereal day is $23^h\ 56^m\ 4^s{\cdot}09$ of a mean solar day, and the mean solar day is $24^h\ 3^m\ 56^s{\cdot}55$ of a sidereal day. We have in this article only to do with the mode of obtaining a uniform measure of time, or of intervals of time; this being premised, the subject will be taken up again in the article YEAR.

TIME BALL. [TELEGRAPH, ELECTRIC.]

TIME BARGAIN. [STOCKS.]

TIME OF DESCENT, the technical term for the time employed by a material particle in falling down an arc of a curve under the action of gravity, the mode of obtaining which is explained in VELOCITY. When any number of curves are drawn from a given point, and another curve is so drawn as to cut off from every one of them an arc which is described by a falling particle in one given time, that curve is called *tautochronous*, or a *tautochron*. But when a curve is such as the cycloid, namely, that a particle, wherever placed, will fall to the lowest point in the same time, such a curve is also called *tautochronous* by various writers, and *isochronous* by others. Our only object in inserting this article has been to note this confusion of language.

TIN (Sn). One of the first known metals. Its early history is intimately associated with that of our own country, for three thousand years ago the Phœnicians regularly visited the southern shores of this island, and carried on smelting operations for tin.

The alchemists called tin *Jove*, or *Jupiter*, and gave it the sign ♃, indicating that they thought it to be one half silver and the other half acrimony.

The chief ore of tin is the binoxide. [TIN, in NAT. HIST. DIV.] It is roasted to peroxidise iron, and volatilise arsenic and sulphur; washed, to remove sulphate of copper and the oxide of iron; reduced to the metallic state by charcoal; and refined by fractional fusion.

The equivalent of tin is 59.

Tin has a high metallic lustre; its colour is silver-white with a tinge of yellow; in tenacity it is exceeded by several of the metals, but is very ductile, and, as *tinfoil*, is met with in plates varying from 1–250th to 1–1000th of an inch in thickness. It suffers but little change on exposure to the atmosphere, and is unaffected by moisture. Tin is inelastic but very flexible, and when bent produces a peculiar crackling noise, termed the "cry" of tin; the latter effect, as well as the heat rendered sensible during flexion, is due to the mechanical alteration in position, and consequent friction, of the particles of the metal. When rubbed, tin imparts to the fingers a peculiar and somewhat persistent odour. It is a good conductor of heat and electricity; has a specific gravity of 7·292; melts when heated to 442° Fahr., and at a higher temperature burns with a brilliant white light. Tin, like iron, remains in a passive state when plunged into very strong nitric acid; on diluting with water, however, the metal is violently acted on, much nitrous vapour is evolved, and hydrated binoxide of tin is formed. Hydrochloric acid dissolves it with evolution of hydrogen; aqua regia converts it into bichloride; cold sulphuric acid does not affect it, but when hot converts it into sulphate, sulphurous acid escaping. The fused alkalies also oxidise tin, hydrogen being given off. At ordinary temperatures tin is not brittle, but when heated to near the fusing point it may be powdered with facility: the operation is most conveniently performed by pouring the melted metal into a wooden box and well shaking for a few minutes.

Oxygen and *Tin* combine in three proportions, forming—

Protoxide of tin	SnO
Sesquioxide of tin	Sn_2O_3
Binoxide of tin	SnO_2

Protoxide of Tin (SnO) cannot be procured perfectly pure by direct action: the best method of preparing it is to evaporate a solution of protochloride of tin carefully to dryness, and then triturate it in a mortar with excess of crystallised carbonate of soda, which decomposes the chloride, and leaves the protoxide of tin. When this has been washed and dried carefully, it is of a fine bluish-black colour, is very soluble in hydrochloric acid, and when heated in the air takes fire, burns, and is converted into peroxide. The density of protoxide of tin is 6·66; it is soluble in solution of potash and soda, but not in ammonia, nor do the alkaline carbonates dissolve it. The alkaline solutions of this oxide gradually deposit metallic tin, and peroxide remains in solution. Its salts very quickly absorb oxygen from the air, and form compounds which readily yield oxygen; and it is on this account that it converts the sesquioxide of iron into protoxide, and precipitates silver, mercury, and platinum in their metallic state. With gold, a purple compound is formed, known by the name of the *purple powder of Cassius.*

Hydrated Protoxide of Tin (SnO, HO) precipitates as a white powder on adding together solutions of protochloride of tin and carbonate of soda.

Sesquioxide of Tin (Sn_2O_3) is formed by mixing fresh precipitated and moist hydrate of peroxide of iron with a solution of protochloride of tin, as free as possible from hydrochloric acid. By the mutual action of these substances a slimy gray matter is thrown down, which is generally slightly yellow, from the presence of a little peroxide of iron. It is probably a definite ***stannate of protoxide of tin*** (SnO, SnO_2). It is soluble in hydrochloric acid, and also in ammonia, which last property distinguishes it from the protoxide; and it is distinguished from the peroxide by giving a purple precipitate with the salts of gold.

Binoxide or Peroxide of Tin.—One variety of this results from the action of strong nitric acid upon tin. Dried in air, it contains Sn_5O_{10}, 10HO; at 212° it loses half its water ($HO, Sn_5O_{10} + 4Aq$), and by exposure to a red heat becomes anhydrous and of a straw-yellow colour. It is known in commerce as *putty powder,* and is used for polishing plate. In the hydrated state it is insoluble in hydrochloric or nitric acids, but is freely dissolved by the alkalies forming salts, which do not crystallise, but which may be obtained in a granular state: that of potash contains ($KO, Sn_5O_{10} + 4Aq$). It is distinguished from the next form of binoxide of tin by the name ***metastannic acid.*** When its hydrate is moistened with protochloride of tin, a beautiful golden-yellow ***metastannate of tin*** ($SnO, Sn_5O_{10} + 4Aq$) is formed.

When carbonate of lime or baryta is added to excess of bichloride of tin, a gelatinous binoxide is thrown down. Unlike metastannic acid, this variety is readily soluble in nitric or hydrochloric acids. It is called ***stannic acid,*** has the formula HO, SnO_2, and combines with the alkalies to form crystalline ***stannates.*** The ***stannate of soda*** ($NaO, SnO_2 + 4Aq$) is largely used by the dyer and calico-printer as a mordanting agent. By a heat of 284° Fahr., stannic acid is converted into metastannic acid.

Binoxide of tin renders glass semi-opaque or opalescent. It is an ingredient of most enamels.

Chlorine and Tin combine to form the protochloride and the perchloride. The *protochloride* ($SnCl + 2Aq$) is prepared by dissolving the metal in hot hydrochloric acid till the evolution of hydrogen gas ceases: the solution is colourless, and deposits crystals, which sometimes are acicular, and at others prisms of considerable size. When heated to about 212°, the water is nearly expelled; at a higher temperature, hydrochloric acid is evolved, and oxichloride of tin remains. It is soluble in a small quantity of water, but decomposed by a large quantity, oxichloride of tin being precipitated.

The protochloride of tin is used as a mordant in calico-printing, under the name of ***salts of tin,*** and in chemical investigations as a deoxidising agent, acting in the mode already described.

Protochloride of tin may also be obtained by distilling a mixture of equal weights of granulated tin and bichloride of mercury, or by transmitting hydrochloric acid gas over tin heated in a glass tube; in all these cases it is free from water, and is a gray solid, of a resinous lustre, which fuses below redness and sublimes at a high temperature. It is commonly known as *butter of tin.*

Perchloride or *Bichloride of Tin* ($SnCl_2$) may be prepared in several modes: first, by heating the protochloride in chlorine gas; second, by dissolving the hydrated peroxide in hydrochloric acid; third, by putting tin into the mixture of hydrochloric and nitric acid, called *aqua regia,* which yields nascent chlorine; fourth, when a mixture of 1 part of tin with 4 parts of bichloride of mercury is distilled with a gentle heat, a colourless limpid liquid is obtained, which fumes strongly in moist air; this is the bichloride of tin, formerly known by the name of the fuming liquor of Libavius. It boils at 239·5° Fahr., is rendered solid by the addition of one-third of its weight of water, and dissolves in a larger quantity. By the action of alkalies it is decomposed, hydrated peroxide of tin being precipitated.

A solution of this salt under the name of ***nitromuriate of tin,*** or *composition,* is extensively used in dyeing and calico-printing. It forms double salts with alkaline chlorides.

Sulphur and Tin combine in three proportions. The *protosulphide* (SnS) is prepared by adding to melted tin an equal weight of sulphur, and stirring the mixture till combination is effected; the product is to be powdered when cold, mixed with an equal weight of sulphur, and thrown in small portions into a hot crucible, and eventually heated to redness. It is of a bluish-black colour, has a metallic lustre, fuses at a red heat, and when cooled has a lamellated texture. When hydrosulphuric acid gas is passed into a solution of protochloride of tin, a similar compound is obtained. Hydrochloric acid dissolves protosulphide of tin with the evolution of hydrosulphuric acid gas, a solution of the protochloride of tin being formed.

Sesquisulphide of Tin (Sn_2S_3).—To prepare this, finely-powdered protosulphide of tin is to be mixed with a third of its weight of sulphur, and the mixture is to be heated to moderate redness until sulphur is no longer volatilised. It has a deep grayish-yellow colour, and when strongly heated is re-converted to the state of protosulphide; when heated in hydrochloric acid, hydrosulphuric gas is given out.

Bisulphide of Tin (SnS_2) may be prepared in different modes. When hydrosulphuric acid or hydrosulphate of ammonia is added to a solution of bichloride of tin, a bulky precipitate of a dirty yellow colour is obtained; this is hydrated bisulphide of tin: in the dry way it is procured by heating in a retort 12 parts of tin amalgamated with 6 parts of mercury, rubbed up with 7 parts of sulphur and 6 of chloride of ammonium; the mercury facilitates the combination of the tin and sulphur, and the ammoniacal salt, by its evaporation, appears to prevent the temperature becoming so high as to decompose the bisulphide of tin formed. This substance, formerly known to the alchemists by the name of ***Aurum musivum,*** or ***Mosaic gold,*** is in crystalline scales, and sometimes in six-sided plates, of a golden-yellow colour and metallic lustre. It is not soluble in any acid, but nascent chlorine, in the form of what is called *aqua regia,* dissolves it; it is soluble also in solution of potash and soda, forming what have been termed ***sulphur salts.*** It is used in the arts to give an appearance of bronze to the surface of metals.

Phosphide of Tin is readily formed by adding phosphorus to the melted metal; it is of a silvery-white colour, and soft enough to be cut with the knife. After fusion it crystallises on cooling; when thrown upon a red-hot coal, the phosphorus burns. This compound does not appear to have been accurately analysed. When phosphuretted hydrogen is made to act upon a solution of protochloride of tin, a phosphide is formed, which is readily oxidised by the action of the air.

Iodides of Tin.—To prepare the *protiodide* (SnI), 2 parts of granulated tin are to be heated with 5 parts of iodine; the resulting iodide is a red translucent substance, very fusible, soluble in water, and volatile at a high temperature.

The *Periodide of Tin* (SnI_2) is formed by dissolving the hydrated peroxide of tin, precipitated by an alkali from the solution of the bichloride, in hydriodic acid; it forms crystals of a silky lustre, which are resolved by boiling water into peroxide of tin and hydriodic acid.

Selenide of Tin.—When tin is fused with selenium, they combine with the evolution of light. The compound formed is a spongy mass, of a gray colour and metallic lustre; when heated, selenium is expelled and peroxide of tin remains.

OXISALTS OF TIN.

Protonitrate of Tin is formed by dissolving either the metal or the protoxide in dilute nitric acid. A yellow uncrystallisable solution is obtained: by exposure to the air it absorbs oxygen, and peroxide of tin is precipitated.

Pernitrate of Tin.—When tin is acted upon by strong nitric acid, the peroxide formed remains entirely insoluble in the acid; to procure the pernitrate it is best to cause the hydrated peroxide to dissolve in dilute nitric acid. The solution is colourless, and yields no crystals; when diluted or heated, it is rendered turbid.

Sulphates of Tin.—By boiling excess of tin in sulphuric acid, a solution is obtained from which colourless acicular crystals of sulphate of tin (SnO, SO_3) are deposited. When, on the other hand, tin is boiled in excess of sulphuric acid, or hydrated peroxide of tin is dissolved in the acid, persulphate of tin is obtained in solution, but it cannot be made to crystallise.

Phosphates of Tin.—When phosphate of soda is added to a solution of protochloride of tin, an insoluble white precipitate of protophosphate is obtained; the perphosphate, also an insoluble colourless precipitate, may be procured by adding the phosphate of soda to a solution of perchloride of tin.

The characters of the salts of tin are as follow:—The protosalts are white, and the solutions of them are usually colourless; their taste is astringent and metallic, and highly disagreeable; when in solution, they rapidly absorb oxygen, and are converted into the corresponding persalts.

When a plate of lead or zinc is put into a solution of tin, the latter is thrown down in the metallic state. Ferrocyanide of potassium occasions a white gelatinous precipitate when dropped into these solutions, and sulphide of potassium or sodium or sulphuretted hydrogen occasions a coffee-brown precipitate in the salts of the protoxide of tin; neither gallic acid nor infusion of galls occasions any precipitate. When chloride of gold is poured into solutions of protoxide of tin, a purple-coloured precipitate falls. A solution of potash or soda throws down a white precipitate, which dissolves in excess of the alkali. If the solution be boiled, a black powder falls, which is metallic tin; while a compound of peroxide of tin and potash remains in solution. Ammonia throws down a white precipitate, not soluble in excess of the alkali.

Persalts of tin give a white precipitate with caustic alkalies, soluble in excess, the solution not being decomposed on boiling. Sulphuretted hydrogen and sulphide of ammonium give a dirty yellow precipitate, soluble in excess of the alkaline sulphide or in caustic alkalies. Before the blowpipe on charcoal, salts of tin give, in the reducing flame, a white malleable globule of metal.

Estimation of Tin.—This is usually effected in the state of binoxide, of which 78·66 per cent. is metal.

ALLOYS OF TIN.

Most of the malleable metals are rendered brittle by alloying with tin: it combines readily with potassium and sodium, forming brilliant white alloys, which are less fusible than tin; the potassium alloy burns readily when it contains more than one-fifth of potassium. With arsenic it forms a metallic mass which is whiter, harder, and more sonorous than pure tin. With antimony tin forms a white, hard, and sonorous alloy. Bismuth forms with tin an alloy which is more fusible than either of the metals separately, a mixture of equal weights melting at 212°; this compound is hard and brittle. Copper and tin form alloys which are well known and highly useful: they are BELL-METAL and BRONZE. [See, also, BRITANNIA-METAL; PEWTER; SOLDER; and GUN-METAL.] With mercury tin readily amalgamates, and the compound is used for silvering mirrors. With iron, tin forms white compounds, which are more or less fusible according to the proportion of iron they contain. *Tin-plate* is of all the alloys of tin the most useful, and the preparation of this and of pewter are the most extensive applications of this very valuable metal.

In making tin-plate the best iron is employed, and, after being thoroughly cleansed from oxide and grease, by immersion in dilute sulphuric acid and scouring, the plates are dipped into a vessel containing melted tin, on the surface of which tallow floats. These and other similar precautions are necessary to secure the uniform adhesion, or rather alloying, of the two metals. Copper may be tinned by a somewhat similar process.

Moiré métallique is tin-plate to which a beautifully crystalline appearance has been given by moistening the warmed plate with a mixture of equal parts of nitric and hydrochloric acids diluted with its own bulk of water. [MOIRÉ.]

TIN, BUTTER OF. [TIN.]

TIN MANUFACTURE AND TRADE. Referring to other articles for notices of the mineralogical, chemical, and medical characteristics of tin, we shall here treat the metal in its manufacturing and commercial aspects.

Under MINING it is explained in what way the ores of tin are extracted from the mines of Cornwall and other places, and by what processes they are mechanically separated from some of the impurities, and broken into fragments. We shall now take up the details from that point.

Smelting and Refining.—After being reduced to a coarse powder, the ore is roasted or calcined in a reverberatory furnace, until it ceases to exhale arsenical vapours. By this, together with some subsequent processes, it is further cleansed from the admixture of foreign matter and prepared for smelting. The ores of tin raised in Cornwall and Devonshire are always smelted within those counties. The smelting works do not generally belong to the proprietors of the mines, but to other parties who purchase the ore from them. The value is determined by a kind of assay. When several bags of ore, of nearly uniform quality, are conveyed to the smelting works, a small sample is taken from each. These samples, after being blended together, are mixed with about four per cent. of ground coal, placed in an open earthen crucible, and heated in an air-furnace until the ore is reduced. The melted metal is poured into a mould, and the drossy substances which remain in the crucible are pounded in a mortar, in order to separate, and to add to the ingot, any minute granules of tin remaining among them. The ratio of good tin to crude ore determines the value.

The smelting of tin-ores is effected by two different methods. In the first and most common, the ore, previously mixed with culm, is exposed to heat upon the hearth of a reverberatory furnace, in which pit-coal is used as fuel; while in the second, which is applied merely to *stream tin* (the tin procured from stream-works), and which is followed in order to obtain tin of the finest quality, the ore is fused in a blast-furnace, in which wood-charcoal is used for fuel.

In the former process the prepared ore, called *schlich*, is mixed with from one-fifth to one-eighth of its weight of powdered anthracite, or culm, to which a little slaked lime is sometimes added as a flux. These substances are carefully blended together, and a little water is added to the mixture to facilitate the operation of charging the furnace, and to prevent the charge from being blown away by the draft at the commencement of the smelting process. From twelve to twenty-four cwt. of the mixture forms a charge. The charge is spread upon the concave hearth of the furnace; then the apertures by which it is inserted are closed and luted, and the furnace is gradually heated, and kept hot for six or eight hours, by which time the reduction of the ore is complete. When the fusion of the ore is finished, one of the apertures of the furnace is opened, and the melted mass is stirred up to complete the separation of the tin from the scoriæ. These scoriæ consist principally of masses of refuse matter from which no more tin can be profitably extracted, and which are therefore immediately thrown away; but among them are pieces which yet retain a considerable quantity of tin, and which are separated and reserved for further processes. So soon as these refuse matters are removed, a channel is opened, by which the melted tin flows from the hearth into a large vessel, where it is allowed to rest for some time, in order that the impurities may separate. When it has settled, the tin is ladled into moulds, so as to form it into large blocks or ingots. These ingots frequently contain portions of iron, copper, arsenic, tungsten, sulphurets and arseniurets, unreduced oxide of tin, and earthy matters which have not passed off with the scoriæ. To remove these the tin is exposed to the process of *refining*, which commences by placing the blocks or ingots on the hearth of a second reverberatory furnace, and applying a moderate heat. This causes the tin to melt and to flow into a basin provided for it, leaving upon the hearth a residuum consisting of a very ferruginous alloy. Fresh blocks are then placed in the furnace, without removing the unmelted remains of the former, until about five tons of tin have flowed into the basin. This part of the process is termed a *liquation*, and is followed by the actual refining, which is usually effected by plunging billets of green wood into the melted tin in the refining basin, by means of an apparatus erected near it. The heat occasions the disengagement of considerable volumes of gas from the wood, and thus a kind of ebullition is produced in the tin, which causes the lighter impurities to rise to the surface in a frothy form, and the heavier to fall to the bottom. The scum is taken off and returned into the furnace; and when the tin is sufficiently boiled, the green wood is lifted out, and the whole is allowed to settle, in doing which the purest tin rises to the top, that with a trifling admixture of foreign metals remains in the middle, while the foulest portion sinks to the bottom. When the mass becomes so cool that no further separation can take place, the tin is again ladled into moulds. The blocks formed from the lowest part of the tin are usually so impure as to need a repetition of the refining process. A similar effect is sometimes produced by an operation called *tossing;* in which, instead of the ebullition produced by the green wood, the mass of melted tin is agitated by a workman repeatedly lifting a quantity of tin in a ladle, and letting it fall into the basin from a considerable height. After continuing this agitation for some time, the surface is skimmed carefully; and if the upper part of the tin be yet too impure for the market, the refining is rendered more perfect by keeping the metal in a fused state, without agitation, until the impurities separate spontaneously. After refining, the tin is cast into blocks of about three cwt. each. The moulds used for this purpose are frequently made of granite; and the tin thus prepared is sold as *block tin.*

It has been stated that the richer portion of the scoriæ left by the process of smelting is reserved for further operations. Such as contain small grains of tin among the slag or refuse are taken to a stamping-mill, and broken and washed in a similar manner to the ore: while those which contain much tin are re-smelted without any previous preparation. From these scoriæ, which are called *prillion,* an inferior kind of tin is produced by a second smelting.

Of the average quality of tin-ore, as prepared for the smelting-furnaces, 20 parts yield from 12½ to 13 parts of metallic tin, or from 62½ to 65 per cent.; and the quantity of coal required for producing one ton of tin is about a ton and three-quarters. Respecting the time when this economical fuel was substituted for wood-charcoal in the smelting of tin-ores, authorities are at variance; but it is generally supposed to have been about the year 1680. Whatever may have been the precise time or manner of this improvement, its importance is indisputable; and such is the effect of the superior economy of this and other metallurgic operations as performed in England, that experiment has shown the possibility of bringing tin-ore from the Malay countries to this island for the purpose of smelting, and sending the tin back to the East at a lower price than it can be produced for on the spot.

The smelting or reduction of tin by the blast-furnace, with wood-charcoal, is practised on a limited scale for the production of tin of the greatest possible purity. The finest ores supplied by stream-works, and the finer tin sands, are selected for this operation; and as these are free from many of the impurities found in other ores, they do not require calcination. The works in which blast-furnaces are employed are commonly called *blowing-houses.* The furnaces used are about six feet high; the long narrow chimney, after proceeding for some distance in an oblique direction, contains a chamber in which the metallic dust carried off by the blast is deposited. The furnace is lined with a vertical cylinder of cast-iron, coated internally with loam; and it has an opening near the bottom, by which the blast is introduced, either from large bellows or from cylinders. No substance is added to the ore and charcoal, unless it be the residuary matter of a previous smelting; and the proportion of charcoal consumed is about one ton and six-tenths for every ton of tin produced. The melted tin runs from the furnace into an open basin, whence it is run off into a large vessel in which it is allowed to settle. The scoriæ which flow with the metal into the basin of reception are skimmed off, and separated into two portions, one consisting of such as retain tin oxide, and the other of such as have no oxide, but contain tin in a granulated state. The subsequent operations are much the same as with block tin prepared in a reverberatory furnace with pit-coal. In order to convert the blocks of tin produced by the blast-furnace process into the form known as *grain tin,* they are heated until they become brittle, and made to fall from a considerable height in a semi-fluid state, thus producing an agglomerated mass of elongated grains.

From a comparison of the results of the two methods of smelting above described, it appears that the reverberatory furnace with pit-coal occasions less loss of metal than the blast-furnace, and is by far the most economical. The superior quality of the tin produced by the other process is attributable partly to the greater purity of the fuel, and partly to the finer quality of the ore selected for the purpose.

Manufacture of Tin-ware.—It is unnecessary here to enumerate the various purposes to which tin is applied in the useful arts, either as an ingredient in many useful alloys, for which its ready fusibility, its cleanliness, and its beautiful appearance, render it especially valuable, or as the basis of chemical compounds used in dyeing, &c. It is rarely employed alone in our metalline manufactures owing to its softness, but when laid in a thin coat upon the surface of sheet-iron by the process of TINNING, it produces a material of extensive use in the manufacture of culinary and other articles. In this country the greater portion of the tin used in the manufacture of articles composed exclusively of that metal is that which is expanded by rolling or hammering, or by a combination of the two operations, into leaves or sheets barely one-thousandth part of an inch in thickness, under the name of *tin-foil*. [FOIL.]

The art of tin-plate working, or of forming sheets of tinned iron into vessels and utensils, depends more on the manual dexterity of the workman than upon any peculiarity in the tools he requires, which are few and simple, consisting of bench and hand-shears, mallets and hammers, steel heads and wooden blocks, soldering-irons, and swages. In the formation of a vessel the first operation is to cut the plates to the proper size and form with shears; and when the dimensions of the article require it, to join them together, which is done either by simply laying the edge of one plate over that of the other, or by folding the edges together with laps, and then soldering them. Similar joints are required when gores or other pieces are to be inserted, and also at the junction by which a cylinder is closed in. The usual method of forming laps, bends, or folds for this or other purposes is to lay the plate over the edge of the bench, and to bend it by repeated strokes with a hammer. After a tin vessel has been rounded upon a block or mandril, by striking it with a wooden mallet, and the seams finished as above described, all its exterior edges are strengthened by bending a thick iron wire into the proper form, applying it to what would otherwise be the raw edges of the metal, and dexterously folding them over it with a hammer. By this means the appearance of the articles is improved, and their durability and strength are greatly increased. A superior kind of tin-ware, commonly known as *block-tin*, is carefully finished by beating or planishing with a polished steel hammer upon a metal stake; by which means the surface, which otherwise appears somewhat wavy, is made very smooth and silvery, especially after it has been polished with dry whiting. It is principally in the production of block-tin wares that *swaging* is resorted to as a ready means of producing grooved or ridged borders or other embossed ornaments. This process consists in striking the metal between two steel dies or swages, the faces of which bear the desired pattern, and are made counterparts to each other. The mouldings round the edges of dish-covers and other similar articles are produced in this way; the swages embossing the pattern in short lengths, and the article being gradually turned round until every part of its circumference has been submitted to their action. The lower die is usually fixed in an apparatus to which moveable guides are attached to insure the correct position of the article to be operated on, and the upper is made in the form of a hammer, the handle of which is pivoted so as to insure its descent in precisely the right position. Sometimes the requisite power is applied by simply working the upper swage or swage-hammer itself; but in other cases the head of the swage-hammer is struck with a mallet. Very many ornamental articles are produced by embossing or stamping tin-plate, in the same manner as other metallic sheets, with a fly-press or other machinery. Cheap coffin-plates are manufactured at Birmingham in this way; and these and similar articles are sometimes lacquered, painted, or japanned. A very beautiful method of ornamenting tin wares by producing a crystallised appearance on the surface was much practised a few years since, under the name of *moiré métallique*. It is described under MOIRÉ.

Tin forms the principal ingredient in various kinds of pewter and other white metallic alloys, which are manufactured into domestic utensils by casting, stamping, and other processes in which much ingenuity is displayed. The *Britannia metal* manufacture was commenced on a large scale at Sheffield, where it is still carried on, about the year 1770; and the brilliancy, lightness, and cheapness of the wares, which, when well made, greatly resemble silver, have secured for them a very extensive sale in this and other countries. The tin is first melted and raised to a red heat in a cast-iron pot, and then antimony, copper, and brass are successively poured into it from the crucibles in which they have been melted; the mass being stirred during the operation, to complete the mixture. The fusion being completed by the continued application of fire under the pot, the metal is removed by ladles to cast-iron boxes or moulds, in which it is cast into slabs fifteen inches long, six inches wide, and one inch thick; or if for casting small articles, into smaller moulds to form it into convenient ingots. The thick slabs of metal are then extended by passing them between polished steel rollers until they are reduced to the required degree of tenuity. The principal consumption is for candlesticks, tea-pots, coffee-biggins, and other vessels for containing liquids. The feet of candlesticks, the bodies of tea-pots, and other articles having embossed work, are stamped between dies; and when the shape of the article will not allow it to be stamped in one piece, it is stamped in halves, which are subsequently fitted and soldered together. Articles approaching the globular form may in like manner be stamped in three or more pieces. Plaster casts are produced of the required pattern, either from original models or designs, or from manufactured articles of silver; and from these are made moulds or dies of fine hard pig-iron, which, with a very little finishing, form dies fit for stamping so tractable a metal. When very thin, it may even be stamped in dies of brass or of spoon-metal. The great facility with which this alloy may be moulded to any required form is illustrated by the operation termed *spinning*, by which the bodies of tea-pots with concentric circular swells are usually formed. [SPINNING.] Many small vessels, spoons, and other articles are cast in an alloy somewhat harder than that which is rolled into sheets. The facility with which Britannia metal may be run into any shape and cut in the lathe, as for turning measures and small vessels previously formed by casting, is a great recommendation to the manufacturer. Articles of this metal are cleaned from the oil, resin, and other impurities acquired during their formation, by boiling in water containing soap; after which they are polished, either by hand, or more commonly by the buff and brush set in motion by a steam-engine. After buffing and brushing, the articles are boiled in a solution of pearlash, and finally hand-brushed and hand-polished by an application of soft soap, a little oil, and powdered rotten-stone. This operation is usually performed by females; as it is found that no instrument can supply an effectual substitute for a soft hand, which is one of the first requisites inquired for when persons apply for work in this department.

Produce and Trade.—The history of the trade in tin commences with the very earliest records of commercial intercourse with the British islands. We shall only notice it, however, as it has existed within the last two centuries. Davenant gives some interesting information concerning it soon after the middle of the 17th century. In 1663 our exports of tin to all foreign countries amounted to 153 tons; in 1669 to 240 tons; in the three years of peace, from 1698 to 1700, on an average to 1297 tons; and in the ten years of war, from 1700 to 1710, on an average to 1094 tons. In these last ten years the annual purchases of the Dutch amounted to 300 tons, of the estimated value of 21,374*l.* But the produce of the mines more than kept pace with the increased demand; and when Davenant wrote, Queen Anne had between 4000 and 5000 tons of tin on hand, a quantity equal to four or five years' consumption. The produce of the mines went on increasing, and the accumulation to which Davenant alludes is only half a year's produce of the mines at present. From 1750 to 1785 the produce of the mines varied from 2273 tons to 3005 tons; the average price being 64*s.* 6*d.* per cwt. From 1789 to 1816 the annual average quantity was 2875 tons at 79*s.* 9*d.* per cwt. From 1817 to 1837 inclusive, the annual average was 4211 tons, and the average price paid to the tinner was 73*s.* the cwt. In 1787 Banca tin was imported into this country for the first time, and the price of Cornish tin soon fell to 58*s.* the cwt., and would have declined still further if a new market had not been opened. The purser of an Indiaman, who took some tin from the Molucca islands to China in 1787, found the speculation so profitable that the East India Company were induced to direct their attention to the trade, and the Company entered into arrangements with the Cornish tinners for an annual supply. The purchases of the company were made at low prices, but the tinners were indemnified by the artificial scarcity which raised prices in the home market. At first the Company paid only 68*l.* 13*s.* 4*d.* the ton, delivered on board in London; this gradually rose to 80*l.* The connection finally ceased in 1817, as the supply of the home market had become more profitable.

On account of the increasing consumption at home, the portion exported gradually lessened from 7-10ths to 1-5th of the whole. Most of the foreign tin imported is for re-exportation; for it can be supplied to the continent cheaper than English tin. A duty was formerly paid upon all tin raised in Cornwall, to the duchy; but as the mode of stamping the blocks, for the estimation of duty, was very inconvenient, the duty was commuted in 1838 for a perpetual annuity; the duty amounted to about 5*s.* per 120 lbs. Under the tariff of 1842, foreign tin-ore was rendered admissible on payment of a customs' duty of 50*s.* per ton. At present the duty is very light—free if unmanufactured, and 10*s.* per cent. if manufactured. The produce of the British tin mines from 1848 to 1855 varied from 6000 to 7000 tons a year. In 1857 it reached the large amount of 10,000 tons. So varying is the quality, that the price in the last-named year ranged from 18*l.* to 93*l.*; the total value was 750,000*l.*, giving an average of about 75*l.* per ton. This was the value of the ore itself. The metallic tin, after smelting and refining, ranged from 108*l.* to 146*l.* per ton. The English mines which were most productive in that year were the Great Huel Vor, Dolcoath, Carn Brea, Par Consols, and Providence; the produce ranged from 54,000*l.* down to 23,000*l.*, from these five mines.

In the last financial year (1860), there was imported 58,000 cwts. of tin, in blocks, ingots, bars, and slabs; and the exports in the same year amounted to 55,000 cwts. of unwrought tin, besides 1,500,000*l.* in value of tin-plates, in which the greater part of the weight is of iron.

TIN, MEDICAL PROPERTIES OF. It cannot be asserted that tin in a metallic state has no influence over the human system, as many respectable writers affirm that tin-filings are decidedly anthelmintic, and that this is not owing to mechanical irritation of the worms causing them to be detached from the surface of the intestines; it is stated that water in which tin has been boiled, and wine digested in a tin vessel, are also anthelmintic. Others, denying to tin any inherent power over worms, have attributed these effects to the presence of a small portion of arsenic. Be this as it may, it is a very crude method of treating worms to exhibit such a material as tin-filings. [Anthelmintics.] Even oxide of tin is of doubtful efficacy, as might be expected from its extreme insolubility. Its powers may be heightened by occasionally meeting with acids in the stomach, such as the hydrochloric, and therewith forming a chloride. Two compounds of chlorine with tin are known, one the protochloride, the other the bichloride. Both of these are exceedingly soluble; the latter so much so that it can with difficulty be kept in the solid state, and more frequently occurs in the liquid state, and is then called the spiritus fumans Libavii, or butter of tin. The former is much used by dyers, among whom, when in the solid state, it is called *salt of tin*, and when liquid, *spirit of tin*. In the former condition, it has sometimes been mistaken for common salt: it has thus been the source of poisoning, though it is not very active when introduced into the stomach. A few grains of it injected into the jugular vein prove rapidly fatal to dogs. In case of any of it being swallowed, emetics or the stomach-pump, demulcent drinks, such as milk, and, if necessary, moderate venesection, may be employed, followed after a time by vital stimulants. A very weak solution of protochloride of tin in distilled water is used as a lotion in chronic cutaneous diseases. It has been thought by some to be dangerous to allow fluids containing acids, such as the weak acid wines, or cyder, or even fatty, saline, or albuminous substances, to remain long in tin-vessels, as an injurious action of these on the tin is supposed to occur. If any serious effects have ever followed from such a cause, it is most likely that these vessels were only coated superficially with tin, which being rubbed off, exposed the more potent metal beneath to the solvent power of these substances. It is, therefore, prudent to examine from time to time all copper and other vessels to see that the tinning is entire. For small dishes the German enamelled stew-pan is to be commended.

TINCAL. [Boracic Acid.]

TINCTURES are solutions of the active principles, mostly of vegetables, sometimes of saline medicines, and more rarely of animal matters, in certain solvents. From possessing more or less of colour, they have obtained this name. They are distinguished according to the kind of solvent employed. When alcohol is used, they are termed *alcoholic* tinctures, or more generally simply *tinctures;* when sulphuric ether is used, they are denominated *etherial* tinctures. When wine is used, though differing little from pure alcohol, the term *medicated wines* is applied to them; and when the process of distillation is employed to aid the extraction, particularly of volatile oils, the result is termed a *spirit*, such as of rosemary. Ammonia is sometimes conjoined, and the proceeds termed an *ammoniated* tincture. In some cases less of the principal ingredient is taken up or dissolved when ammonia is used, than when simple alcohol is employed, as in the tinctura guaiaci ammoniata. Formerly some tinctures were called *essences*, from the term *esse*, it being thought that they contained only the purer or more refined portion, the alcohol leaving all the baser principles, such as the starch, gum, woody fibre, &c., undissolved: *quintessence* was a still higher degree of this. These terms are now disused by pharmaceutists, though retained in popular language. *Elixirs* differ only from being of a greater consistence: they are not unfrequently turbid from the extractive matter suspended in them. Tinctures are further distinguished into simple and compound. They are called *simple* when one substance only is submitted to the solvent; *compound*, when two or more are. Another important distinction among tinctures is founded upon the degree of strength of the alcohol employed. Where the active principle is nearly pure resin, a strong spirit is needed; when much gum is associated with the resin, a weaker is required. Hence some tinctures are prepared with *proof* spirit, as the greater number; a few with *spirit above proof;* and some with *rectified spirit*.

A well prepared tincture should be clear, possessing the colour of the article which is its base, and partaking in an eminent degree of its characteristic odour and taste. As a general rule, five or six parts of the liquid chosen is to be used for one part of the solid material, which is to be bruised or comminuted before being submitted to maceration. The maceration, which should be conducted in well-stopped glass vessels, is generally continued for fourteen days, during which the ingredients are to be frequently shaken, and at the end strained. The process of displacement by percolation is also good. The pure tincture is then to be preserved in a tightly-stopped bottle, which should be opaque, or sheltered from the light. From several tinctures a deposit falls down, either from some slow chemical change taking place among the ingredients, or from the evaporation of some of the spirit. This renders old tinctures not unfrequently turbid, and of variable strength. Thus tincture of opium when newly prepared contains one grain of opium in nineteen minims, but after some time one grain of opium is contained in only fourteen minims. This inconvenience may be avoided with all recent vegetables, by forming what are termed "vegetable juices." These are merely the juices of the fresh plant expressed by a powerful wooden press, and the juice allowed to stand twenty-four hours, during which a copious precipitation of feculent matter takes place, which is further promoted by adding alcohol 56° over proof, in the proportion of four fluid ounces to every sixteen fluid ounces of the juice. After standing for twenty-four hours, the juice is to be filtered through bibulous paper (prepared from wool), when it will keep unimpaired for a length of time.

These vegetable juices always retain their purity, and are of the same degree of strength at last as at first. By this means not only is the process simplified, and the time required for their preparation greatly abridged, being reduced from fourteen days to two; but their medicinal efficacy is greater than that of the ordinary tinctures, and, from containing less alcohol, they can be given in cases where the stimulating action of this principle interferes with the effect of the substance dissolved in it, or renders its exhibition improper, as in the case of young children.

In preparing the officinal *spirits*, the directions of the Pharmacopœia are rarely complied with. Most chemists content themselves with dissolving some of the essential oil of the plant in alcohol of the requisite strength, by which much expense and trouble, as well as loss of time, are avoided.

(See a pamphlet on *The Best Method of Obtaining the Most Powerful Vegetable Preparations for Medical Use*, by Edward Bentley.)

TINNING; TIN-PLATE. The art of tinning, or of coating other metals with a thin layer of tin, so as to protect them from oxidation, was known to the ancients, although it does not appear to have been very extensively practised. During many centuries, England procured tin-plate from Bohemia and Saxony, where the manufactory was established near the tin-mines of the Erzgebirge mountains, which were the most extensive in Europe after those of Cornwall. From the time of the invention of tin-plate down to the close of the 17th century, if not later, both England and the whole continent of Europe depended upon the above-named countries for their supply of tin-plate; but about the year 1665 an attempt was made to introduce the manufacture into England. The manufacture was permanently established at Pontypool in Monmouthshire about the year 1730, and soon afterwards in France. About 1740 the manufacture was brought to such perfection in England that very little was imported from foreign countries; the British manufacture was superior to the foreign in glossiness of surface, owing to the plates being drawn under a rolling-mill, instead of being hammered, as was common in those made beyond sea. The difficulty of extending iron, in what may be deemed the infancy of the manufacture, into thin uniform sheets, with a perfectly smooth and clean surface, which is essential to the adhesion of the tin in an equal film, was one of the principal obstacles to the progress of this department of the art of tinning.

The process of tinning depends upon the strong affinity which exists between tin and the metals to which it is applied. The tinning of sheet-iron, as the most important application of the process, will be first noticed. The finest English or Welsh bar-iron, prepared with charcoal instead of mineral coke, and known to the trade as *tin-iron*, is used for making tin-plates. This material is first made into flat bars, or slabs, about 30 inches long, 6 inches wide, and weighing eighty pounds. These bars are made red-hot, and extended by passing them repeatedly between rollers, until they are reduced to about 3·8ths of an inch in thickness. When cooled, the pieces are cut by shears, worked by machinery, into plates about 10 inches by 6, which are repeatedly re-heated and rolled, until they are reduced to as thin a state as the process will conveniently allow. The sheet is then doubled and again rolled until reduced in thickness one-half, after which it is doubled again, and rolled until still further diminished in thickness. When thus brought to the required tenuity, the thin sheet is cut into plates of the sizes required to suit the market (most commonly about 13 inches by 10), and then the several thicknesses or laminæ are separated. After shearing, the plates are piled in heaps, one being laid cross-wise at intervals, to separate the number required to form a *box*. This name is technically applied to 225 plates in all the subsequent processes, although it is not until they are completed that the plates are actually placed in boxes.

The next operation to be performed is the removal of every particle of oxide or other impurity from the surface of the plates. For this purpose each is steeped for a few minutes in a leaden trough containing a weak solution of muriatic acid. The plates are taken out, arranged on the floor in rows, and then removed, by means of an iron rod, to a reverberatory furnace or oven, in which they are submitted to a red heat. The heat to which the plates are exposed, combined with their previous washing in the acid, causes them to throw off a scale of rust or oxide. The plates are then flattened by beating them upon a cast-iron block, and are submitted to a second or *cold* rolling, which removes any warping acquired in the previous processes, gives a high degree of smoothness to their surfaces, and imparts elasticity to the iron. After the *cold rolling* the plates are immersed singly, in a vertical position, in an acidulous preparation consisting of water in which bran has been steeped for nine or ten days, until it has fermented and become slightly acid. In this the plates are kept for ten or twelve hours, and occasionally turned, to insure an equal exposure of every part of their surface; and from the lye-trough they are transferred to a leaden vessel containing diluted sulphuric acid. This trough and the lye-trough are slightly heated by flues, to assist the action of the acid menstrua. The plates are usually agitated in the weak sulphuric acid for about an hour, until they become bright and free from black spots. They are then removed into pure water, in which they are scoured with hemp and sand, to remove any remaining oxide; and in this bath of pure water the plates remain until wanted for tinning; because, even if left for months, they will remain perfectly free from rust.

As the sole object of these operations is to cleanse the iron plates from rust and dirt, it is evident that the details may be varied considerably; but it is not necessary to notice particularly any deviations from the usual process. The *tinning* of the plates is effected in a range of cast-iron pots heated by flues, and forming together an apparatus called the *stow*. The plates are removed one by one from the bath of pure water, and dried by rubbing with bran, after which they are immersed singly in a pot filled with melted tallow or grease, in which they are left for about an hour. The grease preserves the surface from oxidation, and appears also to increase the affinity of the iron for tin. From the grease-pot the plates are removed into the metallic bath, which contains a mixture of block and grain tin, covered with a quantity of grease sufficient to form a layer four inches deep. The mixture of block and grain tin usually contains about equal quantities of each. The tin-bath or pot is heated to such a degree as almost to inflame the fatty mixture upon the surface of the tin; and its dimensions are such that it will receive two or three hundred plates standing upright on their edges. When the plates have remained in the tin-bath about an hour and a half, they are lifted out with tongs, and placed upon an iron grating, to allow the superfluous tin to drain off; but as there still remains upon them much more than the proper quantity of tin, they are afterwards subjected to a process called *washing*. This consists in dipping them into a pot containing a quantity of pure grain-tin in a melted state, then rubbing them with a peculiar kind of brush made of hemp, plunging them again for a moment into the melted tin, and then into a pot filled with clean melted tallow. The heat of this second tin-bath melts and detaches the superfluous and coarser portions of the tin from the plates, and the drossy impurities rise to the surface; while the other portions unite with the grain-tin. The last dip serves to eradicate the marks of the brush, and to replenish the coat of tin wherever it may have been rubbed too thin; and the subsequent immersion of the plates in the grease-pot causes any superfluous metal to run off. Thick plates require the tallow to be cooler than for thin ones, because they retain more heat in themselves. So soon as the workman employed in washing has placed five plates in the grease-pot, a boy lifts the first from it into a draining-pan with a grated bottom; and when the man has placed the sixth in the tallow, the boy removes the second. Notwithstanding the apparently complicated character of the operations just described, they are performed so rapidly, that an expert wash-man will wash and brush twenty-five boxes, or five thousand six hundred and twenty-five plates, in twelve hours.

Owing to the vertical position of the plates during the preceding operations, a selvage of tin accumulates along their lower edge, which is removed by the process called *listing*. This is performed by taking the plates one by one, as soon as they are cool enough to handle, and dipping their lower edges into a pot called the *list-pot*, or *listing-pot*, which contains enough melted tin to form a layer a quarter of an inch thick. The selvage of tin being thus melted, is shaken off by a smart blow with a stick, leaving only a faint stripe, which may be discerned upon all finished tin-plates. After listing, the plates are cleaned from grease by rubbing them, while yet warm, with dry bran; after which they are packed in boxes of wood or sheet-iron.

The tinning of the inner surfaces of cooking utensils and other vessels is performed by scouring the surface until it is perfectly bright and clean; then heating the vessel, pouring in some melted tin and rolling it about, and rubbing the tin all over the surface with a piece of cloth or a handful of tow: powdered resin is used, as in soldering, to prevent the formation of oxide, which would impair the mutual affinity of the metals. Pure grain-tin should be used for this purpose, but it is frequently adulterated with lead. By this means vessels of copper, brass, and cast-iron are tinned internally, and thereby rendered fit for the most delicate culinary operations; and in a similar way any small portions of iron-plate may be coated with tin. Bridle-bits, stirrups, and many other small articles, are tinned by immersing them in fluid tin. So also are pins, as described in PIN MANUFACTURE.

Analogous in many respects to tinning are several processes which have been introduced or described within the last few years. All of these relate to the application of a thin layer of one metal to a thicker portion of another. So far as they are examples of electrotyping, they will be found described under ELECTRO-METALLURGY and PLATING; but most of them occupy a medium place between electrotyping and tinning. Messrs. Morewood and Rogers have obtained patents for coating lead with zinc, depending on the difference of melting-points between the two metals. Lead may also be coated with tin or solder by sprinkling it with sal ammoniac, heating it, and rubbing a stick of tin or solder upon it. Tinned lead may even be added to tinned iron, by sprinkling the surfaces with sal-ammoniac, heating them, placing them in contact, and pressing them between heated rollers. Methods have been devised for coating iron with copper; bearing some analogy to that for making tin-plate; and the resulting product has been recommended for use as a cheap substitute for copper in roofing, sheathing, &c. Messrs. Grissell and Redwood have devised a mode in which this coating of one metal with another has been applied widely. Iron may be coated with zinc, silver, or copper; and zinc with such metals and alloys as melt at a lower temperature. The softer material is fused; the surface is sprinkled with any one among several chlorides or sulphates; and the harder plate is dipped into the molten metal. Certain metals may be coated with silver by dipping them into a bath of mercury before that of silver. At Woolwich Arsenal, a method has been tried of coating iron nails with copper. Some schemes have been brought forward, in which an electric shock, instead of a steady galvanic current, is used to induce deposition of one metal on another.

The trade or commerce in tin-plates is noticed under TIN MANUFACTURE AND TRADE.

TINNITUS AURIUM, ringing in the ears, may arise from many different conditions. It is sometimes due to an unnatural state of the circulation in some part of the ear, the movement of the blood producing a vibration of the nerve which the mind does not distinguish from that produced by sonorous vibrations of the air. But most frequently the sensation is due to some disordered state of the auditory nerve, and is entirely subjective. It is thus perceived in some diseases of the brain, in nervous persons, and in those who are much debilitated; and is a common sign of organic disease of the auditory nerve itself. It is analogous, in these cases, to the subjective sensation of sparks and flashes of light which is perceived in cases of disease of the retina or optic nerve. It may therefore be a sign of a dangerous condition, or a prelude to complete deafness; but in the great majority of cases it is unimportant, depending on some local temporary affection of the ear, or on some disturbance of the digestive organs with which part of the brain sympathises.

TISRI, the first Jewish month in civil reckoning, is written in Hebrew תִּשְׁרִי. The name is not mentioned in the Bible, but it is found on the monuments of Palmyra. Tisri has thirty days, and it corresponds with our September or October: in the present year, 1861, it will begin on the 5th September and end on the 4th October. The first day of the month must not be either Sunday, or Wednesday, or Friday; and to prevent this from occurring, the months of Chisleu and Marchesvan may have a day added or subtracted. The great fast of Kippur [expiation], or day of atonement for the expiation of sins, is commanded for the 10th day of this month in Lev. xvi. 29, and again at xxiii. 27; and so great is the sanctity of this fast, that it is held on the Sabbath, when the case occurs, whereas all fasts but this are observed on another day in such cases. Another fast is kept on the third of the month for the murder of Gedaliah, who was made governor of the Jews by the Babylonians after the capture of Jerusalem. (Jerem. xl., xli.) The feast of Tabernacles is celebrated from the 15th to the 21st of the month, as directed in the 23rd chapter of Leviticus, as a rejoicing at the close of the harvest. A feast for the delivery of the law, and for the dedication of the Temple by Solomon, is held on the 22nd day: in the 8th chapter, 2nd verse, of the 1st book of Kings, where this is related, the month is called Ethanim. [BUL; ETHANIM.]

TITANIC ACID. [TITANIUM.]

TITANIUM (Ti). This metal does not occur in the free state in nature, but as a binoxide (titanic acid) it is not uncommon. In the latter condition, associated with protoxide of iron, it forms titaniferous iron-ore, deposits of which are found in various parts of the world. [TITANIUM, in NAT. HIST. DIV.] The variety known as ilmenite is met with in large quantity in Canada. At Bay St. Paul, on the St. Lawrence, ilmenite is found in large beds from one to three hundred feet long, and ninety feet thick. It is massive, of sp. gr. 4·6, and contains, according to an analysis by Mr. S. Hunt:—

Titanic acid	48·60
Protoxide of iron	37·06
Peroxide of iron	10·42
Magnesia	3·60
	99·68

Another kind of titaniferous iron-ore is met with in enormous quantity in New Zealand, forming, in the state of fine sand, a beach at New Plymouth several miles in extent. The following analyses of specimens taken from different parts of the deposit, will at once indicate the nature of this deposit:—

Oxide of iron	88·45
Titanic acid	11·43
	99·88

Oxides of iron	61·14
Titanic oxide	29·73
Sand	5·13
	96·00

A combination of cyanide and nitride of titanium ($TiCy, 3Ti_3N$) in the form of reddish-brown metallic-looking cubes, is nearly always found among the slags and cinders that occur in the bottom of iron furnaces. These crystals are hard enough to scratch agate, and are attacked only by a mixture of nitric and hydrofluoric acid, or by fusion with nitre.

Titanium may be isolated by heating sodium in the vapour of bichloride of titanium. The small prisms thus obtained are soluble in hydrochloric acid with evolution of nitrogen.

The equivalent of titanium is 25.

Oxygen and *titanium* appear to form three compounds:—

Protoxide of titanium (TiO).—When titanic acid is exposed to a strong heat, a portion of it loses oxygen, and a black mass is formed, which is probably the protoxide. It has an earthy fracture, is insoluble in acids, and is difficult to reconvert to the titanic acid. It has been already mentioned in the Natural History Division of this Cyclopædia that anatase is probably the protoxide of titanium.

Sesquioxide of titanium ($Ti_2O_3 = TiO, TiO_2$).—When rutile or titanic acid is dissolved in hydrochloric acid, a piece of zinc immersed in the solution occasions the formation and precipitation of a deep purple-coloured powder, which is hydrated sesquioxide of titanium. It returns to the state of peroxide very rapidly. It is slightly soluble in hydro-chloric acid, forming a blue solution.

Peroxide of Titanium, Titanic Acid (TiO_2).—Rutile is titanic acid nearly pure; when it is reduced to fine powder and fused in a platinum crucible, with three times its weight of carbonate of potash, titanate of potash is obtained, mixed with some excess of carbonate of potash; this is to be removed by washing with water, and titanic acid is then precipitated by dilution and heat; after washing with dilute hydrochloric acid it is nearly pure. It is quite white, very infusible, and after it has been heated is soluble only in hydrofluoric acid. Its acid powers are feeble; it is insoluble in water, and does not act on vegetable blues; it combines, however, with alkalies and metallic oxides, forming salts which are termed *titanates*.

Titanic acid somewhat resembles stannic and silicic acids. It may be separated from the latter by fusion with bisulphate of potash and subsequent solution of the mass in water, silica remaining insoluble.

Bichloride of Titanium ($TiCl_2$) is formed when chlorine gas is passed over metallic titanium at a red heat. It is a colourless transparent fluid, boils at 277°, and is volatilised, and condenses unchanged. When exposed to the air it deliquesces, and when a few drops of it are mixed with an equal bulk of water, combination takes place with considerable violence and the evolution of intense heat. It absorbs dry ammoniacal gas, and forms ammonio-chloride of titanium ($2NH_3, TiCl$).

Tests for Titanium.—Tincture of galls or ferrocyanide of potassium produce, when added to a solution of titanic acid, an orange-red precipitate.

The other compounds of titanium are but little known. The metal is always estimated in the form of titanic acid.

TITANS (Τιτᾶνες, fem. Τιτανίδες) is the name by which, in the mythology of ancient Greece, a certain class of sons and daughters of Uranus and Gaea are designated. The original name of Gaea was said to have been Titæa, from which Titans was derived. (Diodorus Sic., iii. 56.) The beings generally comprised under the name of Titans were Oceanus, Cœus, Crius, Hyperion, Iapetus, Kronos, Thetys, Rhea, Themis, Mnemosyne, Phœbe, Dione, and Theia (Apollodor., 'Biblioth.,' i. 1, 3; Diodorus Sic., v. 66); but writers, as Stephanus of Byzantium (*s. v.* Ἄδανα), Pausanias (viii. 37, 3), and others, differ both in the names and numbers of the Titans. Uranus had by Gaea two other sets of children, namely, the Hecatoncheires (centimani, or beings with a hundred arms), and the Cyclops; and these two he cast into Tartarus, at which Gaea, their mother, was so indignant that she induced Kronos and the Titans to revolt against their father, Uranus, with the result already told under KRONOS. When Zeus, in his turn, made war against his father, Kronos, the latter again called the Titans to his aid. A struggle ensued, which lasted for ten years, and is celebrated in mythology as the Titanomachia, or war of the Titans. It was terminated by Zeus relieving the Cyclops from Tartarus, and by his gaining with their weapons the victory over the Titans, who were now cast into Tartarus, and were guarded there by the Hecatoncheires, while Zeus and his brothers divided the sovereignty of the world among themselves. (Apollodor., 'Biblioth.,' i. 1 and 2.)

The name Titan has also been given to those superhuman beings who were descended from the Titans, such as Prometheus, Hecate, Latona, Pyrrha, Helios, &c. It moreover occurs as a designation of a very early race of men in Crete and Egypt.

(Lobeck, *Aglaophamus*; Böttiger, *Ideen zur Kunstmythologie*; Völcker, *Mythologie des Japetischen Geschlechtes.*)

TITHES are the tenth part of the increase yearly arising and renewing from the profits of lands, the stock upon lands, and the personal industry of the inhabitants, and are offerings payable to the church, by law. Under the Jewish system, the tenth part of the yearly increase of their goods was due to the priests. (Numbers xviii. 21; Deut. xiv. 22; Levit. xxvii. 30, 32.)

In the earliest ages of the Christian church, offerings were made by its members at the altar, at collections, and in other ways; and such payments were enjoined by decrees of the church, and sanctioned by general usage. For many centuries, however, they were voluntary. But when the church had increased in power, and began to number amongst its members many who adhered to it because it was the prevailing religion, it was deemed necessary to enforce certain fixed contributions for the support of the ministers of religion. The church relied upon the example of the Jews, and claimed a tenth. Meanwhile, the conversion of temporal princes to Christianity, and their zeal in favour of their new faith, enabled the church to obtain the enactment of laws to compel the payment of tithes. In England, the first instance of a law for the offering of tithes was that of Offa, king of Mercia, towards the end of the 8th century. He first gave the church a civil right in tithes, and enabled the clergy to recover them as their legal due. The law of Offa was at a later period extended to the whole of England by King Ethelwulph. (Prideaux, 'On Tithes,' 167.)

At first, though every man was obliged to pay tithes, the particular church or monastery to which they should be paid appears to have been left to his own option. In the year 1200, however, Pope Innocent III. directed a decretal epistle to the archbishop of Canterbury, in which he enjoined the payment of tithes to the parsons of the respective parishes. This parochial appropriation of tithes has ever since been the law of England. (Coke, 2 'Inst.' 641.)

The tithes thus payable were of three kinds—*prædial*, *mixed*, and *personal*. *Prædial* tithes are such as arise immediately from the ground, as grain of all sorts, fruits, and herbs. *Mixed* tithes arise from things nourished by the earth, as colts, calves, pigs, lambs, chickens, milk, cheese, and eggs. *Personal* tithes are paid from the profits arising from the labour and industry of men engaged in trades or other occupations; being the tenth part of the clear gain, after deducting all charges. It is sometimes stated that personal tithes seem to have been generally commuted for the more moderate tribute of Easter Offerings; unless in fishing-towns, or other places where peculiar circumstances have caused a continuance of the primitive usages.

Tithes are further divided into *great* and *small*. The great tithes consist of corn, hay, wood, &c.; the small tithes consist of the prædial tithes of other kinds, together with mixed and personal tithes. This distinction is arbitrary, and not dependent upon the relative value of the different kinds of tithe within a particular parish. Potatoes, for instance, grown in fields, have been adjudged to be small tithes, in whatever quantities planted; while corn and hay in the smallest portions still continue to be treated as great tithes. The distinction is of material consequence, as great tithes belong, of right, to the rector of the parish, and small tithes to the vicar.

No tithes are paid for quarries or mines, because their products are not the increase, but are part of the substance of the earth. There may, however, be tithes of minerals by custom. Neither are houses, considered separately from the soil, chargeable, as having no annual increase. By the common law of England no tithe is due for wild animals such as fish, game, &c.; but there are local customs by which tithe has been paid from such things from time immemorial, and in those places such customary tithes may be exacted. Tame animals, kept for pleasure or curiosity, are also exempt from tithes.

Tithes were originally paid in kind, that is, the tenth wheat-sheaf, the tenth lamb or pig, as the case might be, belonged to the parson of the parish as his tithe. The inconvenience and vexation of such a mode of payment are obvious, but no attempt had been made in this country, till very recently, to introduce a general improvement in the mode of collection. The inconvenience of paying tithes in kind must long since have been felt, and certain modes of obviating it were occasionally practised. Sometimes the owner of land would enter into a composition with the parson or vicar, with the consent of the ordinary and the patron of the living, by which certain land should be altogether discharged from tithes, on conveying other land for the use of the church, or making compensation. In other words, the owner of the land purchased an exemption from tithes. Such arrangements between landowners and the church were recognised by law; but it was found that they were often injurious to the church by reason of an insufficient value being given for the tithes. The acts 1 Elizabeth, c. 19, and 13 Elizabeth, c. 10, were accordingly passed, which disabled archbishops, bishops, colleges, deans, chapters, hospitals, parsons, and vicars, from making any alienation of their property for a longer term than twenty-one years or three lives. In order to establish an exemption from tithes on the ground of a real composition, it is therefore necessary to show that such composition had been entered into before the statutes of Elizabeth. Since that time compositions have rarely been made, except under the authority of private acts of parliament.

Another method of avoiding the payment of tithes in kind was by a *modus decimandi*, commonly called a *modus*. This consists of any custom in a particular place, by which the ordinary mode of collecting tithes has been superseded by some special manner of tithing. In some parishes the custom has prevailed, time out of mind, of paying a certain sum of money annually for every acre of land, in lieu of tithes. In others, a smaller quantity of produce is given, and the residue is made up in labour, as every twelfth sheaf of wheat instead of the 10th, but to be housed or threshed by the tithe-payer.

A large portion of the land of England and Wales is tithe-free from various causes. Some has been exempted under real composition, as already explained, and some by prescription, which supposes a composition to have been formerly made. The most frequent ground of exemption is that the land once belonged to a religious house, and was therefore discharged in the following manner:—All abbots, priors, and other heads of religious houses, originally paid tithes from the lands belonging to them, until Pope Paschal II. exempted all spiritual persons from paying tithes of lands which were in their own hands. This general discharge continued till the time of King Henry II., when Pope Adrian IV. restrained it to the three religious orders of Cistercians, Templars, and Hospitalers, to whom Pope Innocent III. added the Præmonstratenses. These four orders, on account of their exemption, were commonly called the privileged orders. The Council of Lateran, in 1215, further restrained this exemption to lands in the occupation of those religious orders of which they were in possession before that council. Bulls were, however, obtained for discharging particular monasteries from the payment of tithes, which would not otherwise have been exempt; by which means much land has been ever since tithe-free. Another mode by which lands belonging to religious houses became not liable to the payment of tithes was that of *unity of possession;* as where the lands and the rectory belonged to the same establishment, which would not, of course, pay tithes to itself. Yet the lands were not absolutely discharged by this unity of possession, for, upon any disunion, the payment of tithes was revived; so that the union only suspended the payment. The act 31 Hen. VIII. c. 13, which dissolved several of the religious houses, continued the discharge of their lands from tithes, though in the possession of the king or any other person by grant from the crown; and, in consequence of this, the lands of many laymen which were granted by the crown are tithe-free, and the right to tithe and the property in many rectories are vested in laymen. Many monasteries had previously been dissolved by act of parliament, but as no such clause as that contained in the 31 Hen. VIII. had been introduced into other acts, the lands of the monasteries dissolved by them became chargeable with tithes.

The payment of tithes in kind has been a cause of constant dispute between clergymen and their parishioners. With the best intentions on both sides, the very nature of tithes is such, that doubts and difficulties must arise between them: and even where there is no doubt, the form and principle of payment are odious and discouraging. Commutation of the tithes has accordingly been attempted and has been found most successful. Dr. Paley, who saw so clearly the evils of tithes, himself suggested this improvement. "No measure of such extensive concern appears to me so practicable, nor any single alteration so beneficial, as the conversion of tithes into *corn-rents.* This commutation, I am convinced, might be so adjusted as to secure to the tithe-holder a complete and perpetual equivalent for his interest, and to leave to industry its full operation and entire reward." ('Moral and Political Philosophy,' chap. xii.) This principle of commutation was first proposed to be applied by the legislature to Ireland. In addition to the common evils of a tithe system, that country was labouring under another. The mass of the people, who are Roman Catholics, were paying tithes to a Protestant clergy. Resistance to the payment of tithes had become so general that a commutation was deemed absolutely necessary for the safety of the church of Ireland. It was recommended by committees of both houses of parliament in 1832, but not finally carried into effect until 1838.

The statutes for the general commutation of tithes in England are the 6 & 7 Wm. IV. c. 71, the 7 Wm. IV., and 1 Vict. c. 69, the 1 & 2 Vict. c. 64, the 2 & 3 Vict. c. 32, and the 5 & 6 Vict. c. 54. Their object is to substitute a rent-charge, payable in money, but in amount varying according to the average price of corn for seven preceding years, for all tithes, whether payable under a *modus* or composition, or not. A voluntary agreement between the owners of the land and of the tithes is first promoted, and in case of no such agreement, a compulsory commutation is effected by tithe-commissioners; provision being made for the valuation and apportionment of tithe in every parish of England and Wales. Land not exceeding 20 acres may also be given by a parish, on account of any spiritual benefice or dignity, as a commutation for tithes to ecclesiastical persons, but not to lay impropriators.

The complete and final commutation of tithes must be regarded as a most valuable measure. It is perfectly fair to all parties, and is calculated to add security and permanence to the property of the church, and to remove all grounds of discord and jealousy between the clergy and their parishioners. Nor must we omit to mention an improvement in the mode of recovering tithes, consequent upon the commutation. There were formerly various modes of recovery, in the ecclesiastical as well as in the civil courts, and before justices of the peace, all more or less leading to unseemly litigation. The present mode of recovering the rent-charge, if in arrear, is by distraining for it upon the tenant or occupier, in the same manner as a landlord recovers his rent; and if the rent-charge shall have been forty days in arrear, possession of the land may be given to the owner of the rent-charge until the arrears and costs are satisfied. Indeed, the whole principle of the Tithe Commutation Act is to strip tithes of the character of a tax, and to assimilate them as much as possible to a rent-charge upon the land. [TITHING; SHIRE.]

TITHING (*Tithinga*, from the Saxon, *Theothunge*) is an ancient municipal division of land in England under the Saxon kings. The whole country was divided into tithings and hundreds by Alfred the Great. The former was a district containing ten heads of families; the latter comprised ten tithings, or one hundred heads of families. Every tithing had its chief man annually appointed to preside over the rest, who was called the tithing-man or borsholder, and sometimes the headborough or borough's elder. Each of these little communities was bound to keep the peace within their own jurisdiction, and the members were responsible for each other. So important were these associations deemed to be, that no man was allowed to abide in England above forty days without being enrolled in some tithing. Although the institution has long ceased, the name and division are still retained in many parts of England.

TITLE. [VENDORS AND PURCHASERS.]

TITLE-DEEDS. [VENDORS AND PURCHASERS.]

TITLES OF HONOUR are words or phrases which certain persons are entitled to claim as their right, in consequence of certain dignities being inherent in them. They vary in a manner corresponding to the variety of the dignities, or, in other words, with the rank of the possessor. Thus Emperor, King, Czar, Prince, are titles of honour, and the possessors of the high dignities represented by these words are, by the common consent of the civilised world, entitled to be so denominated, and to be addressed by such terms as Your Majesty and Your Royal Highness. These are the terms used in England, and the phrases in use in other countries of Europe do not much differ from them. In fact one European nation seems to have borrowed from another, or all to have taken their titles of honour for this exalted rank from a common original; so that little of the peculiar genius of the European nations can be traced in the terms by which they show their respect for the persons of highest dignity. But it is different when we come to compare them with the Oriental nations. In those seats of ancient civilisation the most extravagant terms of compliment are in use, and a little sovereign of a wandering tribe rejoices in titles of honour numerous and inflated in the highest degree. In the series of Roman emperors, the word Cæsar, originally the name of a family, became a title of honour; Augustus was another; and Pater Patriæ a third.

The five orders of nobility in England are distinguished by the titles of honour, Duke, Marquess, Earl, Viscount, and Baron; and the persons in whom the dignity of the peerage inheres are entitled to be designated by these words, and in any legal proceedings are to be thus designated; that is, the law or the custom of the realm guarantees to them the possession of these terms of honour, as it does of the dignities to which they correspond. They are also entitled to be addressed by such phrases as My Lord, My Lord Marquess, My Lord Duke, and they have usually prefixed to their titles, properly so called, certain phrases, as High and Mighty Prince, Most Noble, Right Honourable, varying with the kind and degree of the dignity possessed by them. The other members of the families of peers have also their titles of honour. Thus the lady of a peer has rank and titles corresponding with those of the husband. All the sons and daughters of peers are Honourable, but the daughters of earls and peers of a higher dignity are entitled to the distinction of being called Lady, and the younger sons of dukes and marquesses are by custom addressed as My Lord.

The orders of nobility in other European countries differ little from our own. They have their Dukes, Marquesses, Counts, Viscounts, and Barons. We cannot enter into the nice distinctions in the dignities of foreign nations, or in the titles of honour which correspond to them.

The Baronet, which is a new dignity, not having been known before the reign of James I., has, besides its name, which is placed after the name and surname of the person spoken of, the privilege of prefixing Sir; and their wives are entitled to the prefix of Dame, and to be addressed as My Lady and Your Ladyship. The title is, like the titles of peers, hereditary.

Another dignity which brings with it the right to a title of honour is that of Knighthood, and this is not hereditary. This dignity is of ancient origin, and, in the form in which we now see it, may be traced far into the depths of the middle ages, if it be not, as some suppose, a continuation of the Equites of Rome. Persons on whom this honour is conferred take rank above the gentlemen and esquires, and are entitled to the prefix Sir to their former name and surname. Their wives are also entitled to prefix the word Dame, and to be addressed by the compellation Your Ladyship or My Lady. The knights of particular orders, as of the Garter, the Thistle, St. Patrick, the Bath, are a kind of select number of the body of the knighthood; and the name of the order to which they belong is ordinarily used by and of them, and thus becomes of the nature of a title of honour. The Bannerets of former ages were a class of knights superior to the ordinary knight-bachelor, forming in fact an order intermediate between the knight, in its ordinary sense, and the baron.

Besides these, there are the ecclesiastical dignities of Bishop and Archbishop, which bring with them the right to certain titles of honour besides the phrases by which the dignity itself is designated. And custom seems to have sanctioned the claim of the persons who possess inferior dignities in the church to certain honourable titles or compellations; and it is usual to bestow on all persons who are admitted into the clerical order the title of Reverend.

There are also academical distinctions which are of the nature of titles of honour, although they are not usually considered to fall under the denomination. Municipal offices have also titles accompanying them; and in the law there are very eminent offices the names of which become titles of honour to the possessors of them, and which bring with them the right to certain terms of distinction.

All titles of honour appear to have been originally names of office. The earl in England had in former ages substantial duties to perform in his county, as the sheriff (the Vice-Comes or Vice-Earl) has now; but the name has remained while the peculiar duties are gone, and so it is with respect to other dignities. The emperor or king, the highest dignity known in Europe, still performs the duties which originally belonged to the office, or at least the most important of them, as well as enjoys the rank, dignity, and honours; and on the Continent there are dukes and earls who have still an important political character.

Whoever wishes to study this subject in all its details, will do well to resort to two great works: one, the late 'Reports of the Lords'

Committees on the dignity of the Peerage;' the other, the large treatise on 'Titles of Honour,' by the learned Selden. The latter was first printed in 4to, 1614; again, with large additions, folio, 1631.

TOBACCO CULTURE AND TRADE. Tobacco is the common name of the plants belonging to the Monopetalous genus *Nicotiana*. Tobacco was the name used by the Caribbees for the pipe in which they smoked; but this word was transferred by the Spaniards to the herb itself. The genus *Nicotiana* contains about forty species, most of them yielding tobacco for smoking, and many of them cultivated in the gardens of Europe. The name *Nicotiana* was given to these plants after Jean Nicot, of Nismes, in Languedoc, who was an agent of the king of France in Portugal, and there procured the seeds of the tobacco from a Dutchman who had procured them in Florida. Nicot sent them to France in 1560.

The botanical characteristics of the tobacco-plant are described under NICOTIANA in the NAT. HIST. DIV.; its medical uses are discussed under NICOTIANA TABACUM in the present Division; and its chemical properties under NICOTINE. We need scarcely revert to the following points: that the common Virginian tobacco, the *Nicotiana tabacum*, is the chief kind; and that the Orinoco, Turkish, and Persian are the kinds ranking next in extent of use.

Cultivation.—The cultivation of tobacco is most extensively carried on in the United States of America. The plant requires considerable heat to come to perfection; but with care and attention, and by treating it as an exotic, it may be very successfully cultivated in much colder climates. The least frost injures it. The seeds of the tobacco-plant are sown in a prepared seed-bed, and carefully protected from frost; for which purpose straw and fern are used. When once the danger of spring frosts is over, they may be safely transplanted into ground which has been laid in narrow beds with intervals between them, dug out deep, and richly manured with sheeps' dung. These beds are two feet wide at top, and two feet six inches at bottom, with sloping sides to keep the earth up; the intervals are only six or eight inches, and serve not only as drains to keep the beds dry, but as paths from which the surface of the beds may be stirred and weeded. Two rows of plants about eight inches high are planted at equal distances along the beds; the rows are sixteen or eighteen inches apart, and the plants at the same distance from each other. In warmer climates the plants are placed three feet apart, as there they grow to a much greater size, and cover more ground. A moist day is chosen for transplanting. The plants are taken up carefully with a small spade or trowel without shaking the earth much from the roots; they are placed slanting in a shallow basket, and thus carried to the prepared beds; they have a stem six or eight inches long. They are inserted into holes made by a proper instrument, so that the fibres of the roots and the adhering earth may be completely buried up to the bottom of the stem. Four or six leaves should be on the plant; if more, the lowest are pinched off. Great attention is paid to the beds all the time the tobacco is growing; weeds are carefully eradicated, and the earth repeatedly stirred between the plants with hoes and narrow spades to accelerate the growth. When the plants acquire a certain size, the lower leaves are pinched off, to increase the bulk of the upper. A fine tobacco-plant should have from eight to twelve large succulent leaves, and a stem from three to six feet high; the top is pinched off to prevent its running and drawing the sap from the leaves, and lateral shoots are carefully pinched off as soon as they appear, to prevent branching. A few plants are left for seed, and of these the heads are allowed to shoot the full length. The seeds are so small and so numerous on a plant, that a few plants produce a sufficiency of seed for the next crop. The plantations are continually examined, and every leaf injured by insects or otherwise is pulled off. Tobacco takes about four months from the time of planting to come to perfection; that is, from May to September, when the leaves are gathered before there is any danger from frost: one single white frost would spoil the whole crop, and cause it to rot. As soon as the colour of the leaves becomes of a paler green inclined to yellow, they are fit to be gathered; they then begin to droop, and emit a stronger odour, and feel rough and somewhat brittle to the touch. When the dew is evaporated and the sun shines, the leaves may be most advantageously gathered, which is done by cutting down the plant close to the ground, or even a little under the surface. They are left on the ground to dry till the evening, taking care to turn them often, that they may dry equally and more rapidly. They are housed before the evening dew falls, which would injure them, and laid up under cover in heaps to sweat during the night, and some mats are thrown over the heaps to keep in the heat. If they are very full of juice, they are sometimes carried out again the next day to dry in the sun; but most commonly they are left to sweat for three or four days, and are then moved and hung up to dry in sheds which allow a thorough draught of air but keep out the rain. Every tobacco-plantation has such buildings, proportioned to the extent of the cultivation. In some places the leaves are now stripped off the stems and strung on packthread to dry. In others the whole plant is hung on pegs placed in rows at regular distances, and fixed on laths which run across the building. When the plants are quite dry they are removed in moist or foggy weather; for if the air is very dry the leaves would fall to dust. They are laid in heaps on hurdles and covered over, that they may sweat again, which they do but slowly. The heaps are carefully examined from time to time to see that they do not heat too much; and, according to the season and the nature of the plants, whether more or less filled with sap, they remain so a week or a fortnight. If the leaves were not stripped off at first, they are taken off now, when the proper fermentation is completed. They are sorted; those which grow on the top of the stem, in the middle, and at the bottom, are laid separately, as being of different qualities. They are tied together in bundles of ten or twelve leaves, again dried carefully, ranged in casks horizontally, and pressed in, by means of a round board, by lever or screw, as soon as a certain quantity has been laid in; the pressure is equal to that of a weight of several tons. This is essential to the safe transportation of the tobacco; and it is thus that the great bulk of it arrives from the places where its cultivation is most extensive, as in America.

The finest tobacco, however, is made into rolls, which from their shape are called *carrots*. The leaves are placed together by large handfuls, and wound very tightly round by strips of fibrous wood or strong grass, at a time when the air is somewhat moist; they partially consolidate, and require only to be rasped to make the finest and most genuine snuff.

The refuse stems of the tobacco are sometimes burned; but it is best to let them rot in the ground, where they are converted into good manure for the next crop. From the high state of cultivation of the land, it is left very rich for any other crop after the tobacco; but as this is quite a garden cultivation, the tobacco recurs very soon on the same ground; the abundant manuring and deep trenching prevent any bad effects from this frequent recurrence.

Manufacture.—Tobacco is packed in hogsheads for shipment: it is done with the greatest care, each bundle being laid separately. They are ranged side by side, and the direction of the points of the leaves is reversed with every alternate row. When the cask is about one-quarter filled, the tobacco is compressed by a powerful lever-press, which reduces the thickness of the layer from about twelve inches to three; and the pressure is continued several hours, that the tobacco may become so consolidated as not to spring up again when it is removed. In this way the cask is filled, by successive stages, until it contains a mass of tobacco-leaves so dense and compact, that a hogshead 48 inches in length, and 30 or 32 inches in diameter, will contain 1000 lbs. weight.

Upon the arrival of the tobacco in this country it is conveyed to bonding-warehouses. Those of the metropolis, which are of immense extent, are situated chiefly at the London Docks, where every cask is opened to examine its contents, and to remove any tobacco which may have been injured in the passage. This arrangement is due to the operation of the high import-duty, which renders it better for the owner to sacrifice tobacco that may have become impaired in value than to pay the duty upon it. For the purpose of examination, the head of the hogshead is knocked out, some of the staves are loosened, and the hogshead is taken completely off from the tobacco. If it be found that, from defective packing, from the action of sea-water, or from any other cause, part of the surface has become so injured as not to be worth preserving, such part is removed, with large powerful cutting instruments, by small quantities at a time. This requires considerable power, owing to the intense compression of the tobacco, especially upon the cylindrical sides of the mass, where the cutters act across the direction of the stalks and leaves. The damaged tobacco thus removed is consumed in a furnace on the premises. The remainder of the mass is accurately weighed, and then returned into the hogshead.

The manufacture of the tobacco-leaves into the numerous varieties of *tobacco* for smoking in pipes—consisting of the leaf cut up into shreds or filaments, and usully divested of the stalk; into *cigars*, which are bundles of the tobacco-leaf rolled compactly together into a convenient form for smoking; and into *snuff*, which consists partly of the stalks of the leaves, and partly of the leaves themselves, cut and ground into the state of powder—is usually conducted by three distinct classes of traders.

The first operation performed upon a hogshead of tobacco, after it has been removed to the manufactory and opened, is the digging out of the solid tobacco with iron instruments. The pieces thus detached are then sprinkled with water, which facilitates the separation of the small bundles from each other, and also of the leaves composing each bundle. If the tobacco be of the kind called hand-work,—that is to say, with the stalks remaining attached to the leaves,—it must now be stripped, unless indeed it be required for the production of a kind of tobacco called *bird's-eye*, which contains a portion of stalk as well as leaf. The removal of the stalks is usually effected in England by women or boys, who fold the leaf along the middle, and, by means of a small instrument, separate the stalks from the leaves, and lay them aside in different heaps. To prepare them for being cut into shreds or filaments, the leaves are pressed together in large numbers in the form of a cake, during which operation they are occasionally moistened, not only to enable them to cake together the more readily, but also in order to improve the subsequent flavour of the tobacco. The details of the machinery employed for compressing and cutting the tobacco vary in different establishments. Originally the cutting apparatus consisted simply of a long knife worked by hand. Hand-engines were then introduced, and such are still partially used, in which the knife is moved by a train of machinery, which also shifts the cake of tobacco between each cut, so as to make it ready for the next. This kind of cutting-engine is turned by a winch-handle, and the motion is regulated by a fly-wheel. Horses have been applied to a similar machine; and, lastly, steam-power has been brought to the aid of the manufacturer, leaving the attendance of men necessary only to place the cake in the engine, to attend to it while at work, and to remove the cut tobacco. Generally speaking, all of these machines act upon the same principle. The cake of leaves is laid upon an iron bed, which is susceptible of a slow progressive motion, and another part of the mechanism gives motion to the knife. The depth of the cake is about two inches; the thickness of the film taken off by each stroke, and consequently the fineness or coarseness of the filaments of tobacco, is regulated by alterations in a train of cog-wheels.

Many circumstances combine to account for the different qualities and appearance of the numerous varieties of tobacco used for smoking. Tobaccos raised in various places naturally present some points of difference; variations will, as already shown, appear in different parts of the same crop; and the retention or rejection of the stalk, the nature and extent of the moistening, and the degree of fineness of the fibres, occasion still further differences. A coarse variety called *shag*, which is used both for chewing and smoking, is formed of the darkest-coloured leaves, well liquored, which darkens them still more. *Pig-tail* tobacco consists of a rope or cord, about as large as the thicker end of a tobacco-pipe, and as long as the manufacturer can conveniently make it. It is produced by a process similar to spinning, and requires the simultaneous aid of a man and two boys.

The manufacture of cigars is described in another article. [Cigar Manufacture.]

Snuff is made either from stalks only, from leaves only, or from a mixture of the two. That known as *Scotch* snuff is made either wholly of stalks, or with a very small admixture of leaves. *High-dried* snuffs owe their peculiar qualities chiefly to a degree of drying which imparts a scorched flavour to them; and innumerable varieties are produced by the choice, mixture, and preparation of different tobaccos. Most of the snuff made near London is ground in mills whose machinery is impelled by the river Wandle, near Mitcham in Surrey. In these mills two kinds of grinding-machine are employed. One consists of two cylindrical stones, several feet in diameter, and one or more in thickness, set up on edge, side by side, upon a circular slab or bed. These stones have a two-fold motion imparted to them, resembling that of a carriage wheel compelled to revolve in a small circle. The effect of this peculiar motion is a grinding action upon the bed where the snuff is laid, peculiarly adapted to the required purpose. Some kinds of snuff, however, are better ground by the other sort of machine, which consists of a kind of rolling pestle, set in motion by an ingenious train of wheels and set of jointed arms or levers. Little is done at the snuff-mills beyond a preparatory drying of the tobacco and the actual grinding; but the snuff usually receives some finishing operations from the maker after it leaves the mill.

Tobacco Trade.—The discoverers of the New World learned the habit of smoking tobacco from the natives; and on their return the practice was at first introduced into Spain and Portugal, and soon spread to other parts of the Continent. The settlers who accompanied Raleigh on his expedition to colonise Virginia, which returned unsuccessful in 1586, introduced the habit into England. Before the establishment of the colony of Virginia in 1606, all the tobacco imported into this country was raised by the Spaniards in the West India Islands. King James's invectives against the use of this weed are now curious matters of history. In 1604 he took upon himself, without the consent of Parliament, to raise the duty on tobacco from 2*d.* to 6*s.* 10*d.* the lb. In 1615 the colonists of Virginia regularly betook themselves to the cultivation of the tobacco-plant, abandoning the manufacture of ashes, soap, glass, tar, and the planting of vineyards, which they had already commenced. James felt that, without abating his well-known aversion to tobacco, in the infancy of the colony this proceeding of the planters must be tolerated. In the first instance he commanded that the production of tobacco should not exceed the rate of a hundred-weight for each individual planter. The cultivation was forbidden in England, and the plants already growing were ordered to be uprooted. At the same time he confined the right of importing the commodity to such persons as he should license for the purpose. In the last year of his reign the exclusive supply of the English market was given to the English plantations in America.

Being regarded as a source of revenue, tobacco is not allowed to be grown in England. In 1786 tobacco paid an import duty of 10*d.* per lb.; it was raised to 1*s.* 3*d.* in 1787, 1*s.* 7*d.* in 1796, and by gradual steps to 4*s.* in 1815, at which it remained till 1825. In the last-named year the duty was lowered to 3*s.* if from foreign countries, and to 2*s.* 9*d.* if from British possessions. The discriminating duty was afterwards removed, the British was raised to the same rate as the foreign, and the duties settled down at these rates—3*s.* on unmanufactured tobacco, 6*s.* on snuff, and 9*s.* on cigars, plus 5 per cent. Down to 1825 an excise as well as a customs duty was levied on tobacco; but in that year the former was removed, except in so far as concerned a license for the traders and a supervision of the trade. Great restrictions are placed on the importation. Specified ports, about thirty in number, are alone permitted to import tobacco. The importer is not compelled to pay the duty at once; he may allow the tobacco to remain in bond, in the queen's warehouses at the several ports, for any space of time not exceeding five years, paying a rent of 4*s.* on every hogshead, cask, chest, or case. Every soldier and sailor on British service in foreign parts may purchase *duty free* to the extent of 2 lbs. of tobacco per month; but all other tobacco must pay the duty before being taken out of bond. As the price of tobacco in bond, after all the expenses of growth and freight have been paid, varies from 3*d.* to 10*d.* (perhaps averaging 6*d.*), it follows that the duty (about 3*s.* 3*d.*) is enormously heavy, and this leads both to smuggling and adulteration. It has been pertinently remarked by Mr. Cooley, that the retail sale of genuine tobacco at 3*d.* per oz. is a commercial impossibility. The tobacco *must* be adulterated, in order to pay the planter, importer, manufacturer, wholesale dealer, and retailer, and to pay also the duty; or, if genuine, then the duty must be evaded by smuggling. The government officers, as well as chemists acting unofficially, have detected sugar, treacle, molasses, malt, roasted grain, chicory, lime, sand, umber, ochre, sea-weed, and leaves or herbs of various kinds, in tobacco. Dye-drugs are often used, not to increase the weight, but to impart a tobacco-colour to adulterants.

Tobacco, as already stated, is not allowed to be grown in England. The acts prohibiting its cultivation did not apply to Ireland till about 1840. Tobacco is extensively cultivated in France, Prussia, Holland, and Belgium, also in the southern provinces of Russia, and in Turkey and Syria. It has as yet made little progress in the British West Indies, and still less in Upper Canada. The tobacco of Cuba holds the highest rank for the excellence of its flavour. Next in favour, perhaps, are the cigars of Manilla. But the cultivation of tobacco is most extensive in the United States. In 1850 the produce in eight states of the Union was estimated at 200,000,000 lbs., of which much more than half was produced in Virginia and Kentucky. About 120,000,000 lbs. of this quantity were exported, and 80,000,000 lbs. consumed at home, amounting to 3¼ lbs. per head on a population of 23,000,000. Professor Wilson, in his Report on the New York Industrial Exhibition, spoke of the so-called *Cavendish* tobacco as being now in very extensive demand in the United States. "It is known as chewing or plug tobacco, and is put up in boxes of various sizes. Those exhibited weighed 38 lbs., and were of various qualities to which different names and prices were attached. 'Ladies' Love' sold at 16 dollars per box, 'Ladies' Twist' at 13, and 'Fair America' at 10. Tobacco for chewing undergoes a process of gradual fermentation, and is then sweetened by the addition of molasses, and either done up into rolls or pressed into cakes; the former is known as *twist*, the latter as *plug*. A good chewer, I am informed, would dispose of 4 to 8 ozs. per day."

The quantity of tobacco imported into this country in 1786 was about 7,000,000 lbs.; in 1796 it rose to 10,000,000 lbs. During the first forty years of the present century it rose gradually from 11,000,000 to 18,000,000 lbs.—a ratio of increase far less than that in the population. A marked advance then took place, and from 1844 to 1860 the import was never less than 33,000,000 lbs. In 1860 the quantity was 49,670,893 lbs., of which 35,412,841 lbs. was retained for home consumption and paid duty, the rest being re-exported. This quantity is a little more than 1 lb. per head per annum for the whole population.

TOBACCO, ACTIVE PRINCIPLE OF. [Nicotine.]

TOBACCO-PIPE MANUFACTURE. The materials of which tobacco-pipes are formed are very numerous. White and coloured earths, porcelain, metals, ivory, horn, shell, costly woods, agate, cornelian, talc, and amber, are among the substances which have been used for the purpose. The forms admit of equal variety; but perhaps the most remarkable is the oriental hookah, in which the smoke is purified by passing through water.

The tobacco-pipes most commonly used in this country are formed of a fine-grained plastic white clay, which is called, from this application, pipe-clay. It is procured chiefly from Purbeck in Dorsetshire, and is purified from all foreign substances by working it with water into a thin paste, and then either allowing it to settle in pits, or passing it through a sieve, to separate the siliceous or other stony matter. The water is subsequently evaporated until the clay becomes of a doughy consistence, when it must be well kneaded to make it uniform. It is finally formed into cubical masses of about one hundred pounds each. From one of these the workman cuts off just enough to make one pipe. Each piece is kneaded thoroughly upon a board, and rolled out to nearly the form and size of a pipe, with a projecting bulb at one end for the formation of the bowl. These pieces are laid aside for some time to dry, and when the clay is sufficiently firm, they are subjected to the curious process of *boring*. The workman takes the roll of clay in his left hand, and with his right inserts the end of an iron needle, previously oiled, in the small end of the roll, and by dexterous management thrusts the needle through the whole length of the roll without penetrating the surface. The bulb is then bent into the proper position to form the bowl, and the piece of clay, with the needle remaining in it, is pressed into a mould to complete its form.

Tobacco-pipe-moulds are formed either of copper, brass, or iron, and each consists of two precisely similar halves, with projecting pins in one half, and corresponding holes in the other, which ensure their exact union. On their inner surfaces, which are hollowed so as to fit the finished pipe, may be added any ornamental device or inscription. One half of the mould being laid flat, the pipe is placed in it, covered with the other half, and then firmly pressed. The bowl is partially hollowed by the finger, and completed by the insertion of an oiled stopper or mould. The wire is thrust backwards and forwards until it becomes visible in the bowl. The wires are now withdrawn, and the pipes are taken out of the moulds, slightly smoothed over, and laid aside to dry. After drying for a day or two, any remaining roughness is removed by means of an instrument of bone or hard wood; and then the pipes are sometimes moulded a second time, and polished with a piece of flint bored with holes, through which the stem is passed repeatedly. Hitherto the pipes are straight in the stem; but before going to the kiln they are slightly bent. It is said that a clever pipe-moulder will make three thousand five hundred in one day. They are fired in a tobacco-pipe-kiln, which consists of a large but very light cylindrical crucible or sagger, with a dome-shaped top, and a circular opening in one side for the insertion of the pipes.

At the Cheltenham Meeting of the British Association, in 1856, Mr. Strong stated that tobacco-pipes are now made more extensively at Glasgow than in any other part of the United Kingdom. There are 600 persons employed, who manufacture, finish, and pack about 2700 gross of pipes per day, or about 120 millions in a year.

A remarkable kind of pipe for smoking is described under MEERSCHAUM.

TOD, an old measure of wool, fixed at two stones, or 28 pounds avoirdupois, by a statute of the 12th of Charles II. As usual, there are several local tods.

TOGA is the name given to the principal outer garment worn by the Romans. The Romans generally wore the same kind of dress as the other Italian nations and the Greeks; the toga alone is by some writers said to have been derived from the Lydians, but this statement probably arose from the belief that the Etruscans had come from Lydia; and that at least a particular kind of toga (the *toga prætexta*) was introduced at Rome at a very early time from Etruria, is expressly stated. (Livy, i. 8; Pliny, 'Hist. Nat.,' viii. 74.) In later times the toga was the peculiar garment of the Romans, which in times of peace they wore both at home and abroad, and whenever they appeared in full dress. Hence they are called *gens togata* (Virgil, 'Æn.,' i. 282) and *togati* (Sallust, 'Jugurth.,' 21), in contradistinction from other nations. The name "toga" was, according to Varro ('De Ling. Lat.,' iv. p. 33, ed. Bipont), derived from *tegere*, "to cover," because it covered the whole body. Gellius (vii. 12) states that in early times it was the only article of dress that was worn, but afterwards we know that it was worn over other dresses. The right of wearing it was the exclusive privilege of Roman citizens of every age and sex. (Servius, 'Ad. Æn.,' i. 282.) Slaves, foreigners. and Romans sent into exile were not allowed to wear it. (Pliny, 'Epist.,' iv. 11; Horat., 'Carm.,' iii. 5, 10.) The peculiarity of the toga as a Roman dress is also indicated by the circumstance that comedies in which Romans appeared on the stage and were represented with their native costume, were called "togatæ," to distinguish them from Greek comedies. As the toga covered the whole body with the exception of the left arm, it could not be worn by a person while at work either at home or in the field. (Juvenal, iii. 171; Livy, iii. 26.)

The material of which the toga was made was woollen cloth, which differed in thickness and fineness according to circumstances and the seasons. Under the empire, persons of rank used to have their togas made of silk. The colour was usually white—probably the natural colour of the wool. Those who appeared before the people as candidates for a public office, wore a particularly white and clean toga (*candida*), whence they derived their name of candidates (*candidati*). On festive occasions, too, it was considered a matter of importance that the toga should be perfectly white. (Horat., 'Sat.,' ii. 2, 60; Cicero, 'In Vatin.,' 13.) On melancholy occasions the Romans wore the *toga pulla*, or "dark-coloured toga." (Cicero, 'In Vatin.,' 13; 'In Verr.,' iv. 24). Towards the end of the republic, and under the empire, the toga, especially that worn by the emperors, was of a purple colour, and was called *trabea*. This custom appears to have been introduced by Julius Cæsar. (Cicero, 'Philip.,' ii. 34; Servius, 'Ad Æn.,' vii. 612.) As early as the time of Augustus, many Romans had left off wearing the toga, and taken to a kind of cloak called lacerna. This induced the emperor, who was fond of restoring ancient customs, to enjoin the ædiles to see that no Roman should appear in the forum or circus without the toga. (Sueton., 'Aug.,' 40.) The toga during the empire continued to be the honourable dress which was worn by persons of rank, as senators, judges, priests, and by clients when they saluted their patrons or received the sportula (Martial, xiv. 125), and especially on all occasions where the emperor was present.

The mode or fashion of wearing the toga appears to have been variously modified in the course of time, although the general character always remained the same. A great difference seems to have existed in the quantity of cloth used for it, as some statues present a richer drapery than others. Its form appears to have been rounded, but respecting that and the manner of putting it on, nothing can be said with certainty, notwithstanding the description in Quinctilian (xi. 3, 137, &c.) and the many statues with togas still extant. (Ferrarius and Rubenius, 'De Re Vestiariâ;' Becker, 'Gallus,' ii.)

Besides the different kinds of togas we have mentioned above, the following must be noticed:—

1. *Toga prætexta* was worn by the children of the nobles, by girls until they married, and by boys until they attained the age of puberty (fourteen), when they exchanged it for the *toga virilis*, also called *pura*, *libera*, or *recta*, which was the usual white toga described above. The prætexta was also the official robe of the higher magistrates of the city and the municipia, as well as of the colonies. The name prætexta was derived from the circumstance of this toga being adorned with a broad purple border (*latus clavus*).

2. *Toga picta* was a toga ornamented with embroidery and gold according to the Etruscan fashion. It was worn by generals in their triumph, whence it was also called *toga Capitolina*. During the empire it was also worn by the consuls and prætors when they were present at the public games.

TOISE, a French measure of six French feet, particularly used in all the older French measures of the earth. [WEIGHTS AND MEASURES.]

TOLEDO, TABLES OF. The Moors brought astronomy into Spain at the beginning of the 11th century, and about the year 1080 tables were calculated for the meridian of Toledo, by Arzachel. Of these tables there was no specific account till the time of Delambre, and no printed publication of them had been made. It was usual to state that they were intended as an improvement on the tables of Albategnius, that their character never was very high, and that the Alphonsine Tables [ALONSINE TABLES] were intended as an improvement upon them. Delambre ('Hist. Astron. Moyenne,' p. 175) examined two manuscript Latin translations of the tables, which he found in the Royal Library at Paris; and his report of their contents is what might have been expected. The theory and numerical quantities employed are in almost every instance those of Ptolemy, and there is only just enough of original observation to establish the fact that the Toledine observers were very bad ones.

TOLENE. A hydrocarbon essence obtained from balsam of Tolu.

TOLL, from the Saxon "tolne;" in German, "zoll" (called in Law Latin "telonium," "theolonium," and "tolnetum," with many other variations, which may be seen in Ducange, all which Latin terms are derived apparently from τελώνιον, "collection of tribute or revenue"), is a payment in money or in kind, fixed in amount, made either under a royal grant, or under a prescriptive usage from which the existence of such a grant is implied, in consideration of some service rendered, benefit conferred, or right forborne to be exercised by the party who is entitled to such payment.

The owner of land may in general prevent others from crossing it either personally or with their cattle or goods, by bringing actions against trespassers, or distraining their cattle or goods. These remedies cannot be resorted to where the owner of the land has acquiesced in its being used as a public way; but in such case there may have been a royal grant, enabling the party to demand a reasonable compensation for the accommodation: this is toll-*traverse*.

Where a corporation, or the owner of particular lands, has immemorially repaired the streets or walls of a town, or a bridge, &c., and, in consideration of the obligation to repair, has immemorially received certain reasonable sums in respect of persons, cattle, or goods passing through the town, such sums are recoverable at law by the name of toll-*thorough*.

An ancient toll may be claimed by the owner of a port in respect of goods shipped or landed there. Such tolls are port-tolls, more commonly called port-dues. The place at which these tolls were set or assessed was anciently called the Tolsey, where, as at the modern Exchange, the merchants usually assembled, and where commercial courts were held.

Another species of toll is a reasonable fixed sum payable by royal grant or prescription to the owner of a fair or market, from the buyer of tollable articles sold there. The benefit which forms the consideration of this toll is said to be the security afforded by the attestation of the sale by the owner of the fair or market, or his officers. In some cases by ancient custom, a payment, called turn-toll, is demandable for beasts which are driven to the market and return unsold. The term toll is sometimes extended to the compensation paid for the use of the soil by those who erect stalls in the fair or market, or for the liberty of picking holes for the purpose of temporary erections; but the former payment is more properly called stallage, and the latter picage; and if the franchise of the fair or market, and the ownership of the soil on which it is held, come into different hands, the stallage and picage go to the owner of the soil, while the tolls, properly so called, are annexed to the franchise.

If tolls are wrongfully withheld, the party entitled may recover the amount by action as for debt, or upon an implied promise of payment; or he may seize and detain the whole or any part of the property in respect of which the toll is payable, by way of distress for such toll. If excessive toll be taken by the lord, or with his knowledge and consent, the franchise shall be seized; if without such consent, the officers shall pay double damages and suffer imprisonment. (Stat. 3 Edw. I. c. 31.)

Grants of tolls were formerly of very ordinary occurrence. But it seems to be very probable that many ancient payments of this description, though presumed, from their being so long acquiesced in, to have a lawful origin under a royal grant, were in fact mere encroachments. The evil was, however, practically lessened by the exertion of the royal prerogative of granting immunities and exemptions from liability to the payment of tolls, either in particular districts or throughout the realm; a prerogative exercised also by inferior lords who possessed jura regalia.

The term "toll" is used in modern acts of parliament to designate the payment directed to be made to the proprietors of canals and railways, the trustees of turnpike-roads or bridges, &c., in respect of the passage of passengers or the conveyance of cattle or goods.

The term toll is applied to the portion which an artificer is, by custom or agreement, allowed to retain out of the bulk in respect of services performed by him upon the article; as corn retained by a miller in payment of the mulcture; also to the portion of mineral which the owner of the soil is entitled, by custom or by agreement, to take, without payment, out of the quantity brought to the surface, or, as it is technically called, *to grass*, and made merchantable, by the mining adventurer. To collect these dues the duke of Cornwall, and other great landholders in the mining districts of the west, have their officers, called "tollers."

TOLLERS. [Toll.]

TOLSEY. [Toll.]

TOLU, ESSENTIAL OIL OF. [Essential Oils.]

TOLU-EUGENYL. [Caryophyllic Acid.]

TOLUENE. [Toluenic Group.]

TOLUENIC GROUP. A cluster of chemical substances, each containing the hypothetical radical *toluenyl* ($C_{14}H_9$).

The chief members of this collection are six in number, namely,—

1. **Toluene or hydride of toluenyl** . $C_{14}H_8 = \left.\begin{matrix}C_{14}H_7\\H\end{matrix}\right\}$
2. **Hydrate of toluenyl** . . . $C_{14}H_8O_2 = \left.\begin{matrix}C_{14}H_7\\H\end{matrix}\right\}O_2$
3. **Toluenyl-sulphurous acid** . . . $C_{14}H_8S_2O_6 = \left.\begin{matrix}C_{14}H_7\\H\end{matrix}\right\}O_2, S_2O_4$
4. **Chloride of toluenyl** . . . $C_{14}H_7Cl = \left.\begin{matrix}C_{14}H_7\\Cl\end{matrix}\right\}$
5. **Toluidine** . . . . . $C_{14}H_9N = N\left\{\begin{matrix}C_{14}H_7\\H\\H\end{matrix}\right.$
6. **Acetate of toluenyl** . . . $C_{18}H_{10}O_4 = \left.\begin{matrix}C_{14}H_7\\C_4H_3O_2\end{matrix}\right\}O_2$

1. *Toluene* ($C_{14}H_7$, H). *Toluol. Retinaphtha. Benzoene. Dracyl.* A colourless, limpid oil, first obtained on submitting balsam of tolu to distillation. It has subsequently been found among the products of the destructive distillation of resin, tar, and wood; and is also formed when Toluic Acid is heated with lime. It may be obtained pure by fractional rectification. The specific gravity of toluene is 0·87; vapour density, 3·260; and boiling point, 237° Fahr. Its odour resembles that of benzole. It is insoluble in water, slightly soluble in alcohol, and more so in ether; with fuming sulphuric acid it forms toluenyl-sulphurous acid, and nitric acid converts it into *nitrotoluene* ($C_{14}H_7$, NO_4). The latter body, called also *nitrobenzoene*, is precipitated on adding water to the mixture of toluene, and forming nitric acid. It is a liquid, has an odour resembling that of oil of bitter almonds; boiling point, 437° Fahr.; and specific gravity, 1·18; a mixture of nitric and sulphuric acids converts it into acicular crystals of *binitrotoluene* ($C_{14}H_6$, $2NO_4$). Several chlorine derivatives of toluene are known.

2. *Hydrate of toluenyl* ($C_{14}H_7O$, HO). The source, composition, and properties of this substance have already been referred to under its synonyme, Benzoic Alcohol.

3. *Toluenyl-sulphurous acid; sulphotoluenic* or *sulphobenzoenic acid* ($C_{14}H_8S_2O_6 + 2$ Aq.). The lead salt of this acid is formed on adding excess of carbonate of lead to the solution of toluene in fuming sulphuric acid. The acid itself is set free on passing sulphuretted hydrogen through the aqueous solution of the lead salt. By evaporation of its solution in vacuo, small deliquescent penniform crystals are obtained.

4. *Chloride of toluenyl* ($C_{14}H_7$, Cl). A heavy liquid resulting from the action of hydrochloric acid gas upon hydrate of toluenyl. Boiling point about 360° Fahr.

5. *Toluidine* ($N(C_{14}H_7)H_2$), or *toluyl-ammonia* is produced by the reducing action of sulphuretted hydrogen upon nitrotoluene. Sulphur having been separated and the solution evaporated, the residue is distilled with potash; toluidine then passes over and condenses to a liquid, which subsequently solidifies.

Toluidine is very soluble in ether, alcohol, and oil. It is but little dissolved by water, but may be obtained in large crystals from its alcoholic solution. It has an aromatic odour, much resembling aniline, and a burning taste. It slightly blues red litmus paper; is heavier than water; is volatile at common temperatures; melts at 104° Fahr., and boils at 388°·4 Fahr. It has the same composition as methyl-aniline, but does not give that beautiful blue colour with chloride of lime that compounds of aniline do.

Toluidine gives stable and crystalline salts with most of the acids. They mostly are soluble in water. The *sulphate of toluidine* contains ($2C_{14}H_9N$, S_2O_6, 2HO); the acid *oxalate* ($C_{14}H_9N$, C_4O_6, 2HO). The *chloroplatinate* ($C_{14}H_9N$, HCl, $PtCl_2$) occurs as a beautiful orange crystalline precipitate.

Nitrotoluidine forms in yellow needles when binitrotoluene is acted on by an alcoholic solution of sulphide of ammonium.

Cyanotoluidine ($2C_{14}H_9N$, Cy_2?) is a body somewhat resembling cyaniline. It is produced on passing cyanogen into an alcoholic solution of toluidine. *Cyanide of toluenyl*, or *cyanonitrile*, is formed on boiling chloride of toluenyl with cyanide of potassium.

Two equivalents of hydrogen in toluidine may, as in the case of other organic bases, be substituted by alcohol radicals. Thus are obtained,—

Ethyl-toluidine . . . . . $N\left\{\begin{matrix}C_{14}H_7\\C_4H_5\\H\end{matrix}\right.$

Diethyl-toluidine . . . . . $N\left\{\begin{matrix}C_{14}H_7\\C_4H_5\\C_4H_5\end{matrix}\right.$

Hydrate of triethyl-toluenyl-ammonium . $N(C_4H_5)_3C_{14}H_7$, O, HO

6. *Acetate of toluenyl* ($C_{14}H_7O$, $C_4H_3O_3$). A colourless, heavy oil, of agreeable aromatic odour resembling that of certain pears. It is formed on adding sulphuric acid to solution of hydrate of toluenyl in acetic acid.

TOLUENYL. [Toluenic Group.]

TOLUENYL-SULPHUROUS ACID. [Toluenic Group.]

TOLUIC ACID (HO, $C_{16}H_7O_3$). A volatile solid, produced when cymene [Cymole or Camphogen] is heated with diluted nitric acid. It occurs in white acicular crystals, very soluble in boiling water, in alcohol, ether, or wood spirit. It is inodorous and tasteless. With strong nitric acid it gives *nitrotoluic acid* ($C_{16}H_7(NO_4)O_4$).

Both toluic and nitrotoluic acids are monobasic and form salts, of which many are crystalline. *Toluate of baryta* contains ($C_{16}H_7BaO_4$), and *nitrotoluate* ($C_{16}H_6Ba(NO_4)O_4$). *Toluic ether* boils at 442° Fahr., and has the composition ($C_{16}H_7(C_4H_5)O_4$). *Nitrotoluic ether* has the composition ($C_{16}H_6(C_4H_5)(NO_4)O_4$).

TOLUIDINE. [Toluenic Group.]

TOLUOLE. [Toluenic Group.]

TOLUONITRYLE. [Toluenic Group.]

TOLUYL-AMMONIA. [Toluenic Group.]

TOMB (in Greek, τύμβος; Latin, *Tumba*; Italian, *Tomba*; French, *Tombe* and *Tombeau*) signifies, in its strict meaning, a mass of masonry or stone-work raised immediately over a grave or vault used for interment; but it is often applied, in a wider sense, to any sepulchral structure. Of primitive sepulchres there are two classes, one of which may be distinguished by the general term *Hypogæan*, that is, subterraneous and excavated; the other, by that of *Hypergæan*, that is, *above-ground*, or raised mounds or tumuli heaped over the dead. Monuments of the first kind are very numerous in Egypt, where they occur in every variety, from the simple rock-hewn tomb to the extensive royal sepulchres consisting of numerous galleries and chambers. The other class presents itself in the Pyramids, which, though far more artificial in form and construction, had no doubt a common origin with the tumulus [Tumulus], which occurs under various designations in every part of the globe.

The extraordinary labour bestowed in excavating or constructing these ancient sepulchres is perhaps not so surprising as the lavishness with which the ancients embellished the subterraneous abodes of the dead, not only adorning them with polychromy and paintings, but depositing in them costly and exquisitely-wrought articles. In this respect there was a striking similarity between the practice of the Egyptians and that of the Etrurians; nor is the coincidence less remarkable from such practice being contrary to that of the comparatively modern Greeks and Romans, whose tombs and sepulchres were chiefly architectural erections intended for external display. Of Egyptian architecture and art, some of the most astonishing memorials are entombed within the earth. Among these are what are called the "Tombs of the Egyptian Kings," at Bibân el Molouk, in one of which Belzoni discovered the sarcophagus, or tomb, properly so termed, which is now in the Soane Museum. [Egyptian Architecture.] In these tombs the entrance passages are narrow, and the first chambers are smaller than those to which they lead. The numerous paintings found in these tombs describe with minuteness the social life and manners of the people, their banquets, their festivals, their amusements, their costume, their furniture, their arts, and the various utensils and implements employed in them. These records prove not only the perfection the mechanic arts had attained, but also the luxurious refinement of those remote ages. The same remark applies to the paintings and frescoes in the subterraneous tombs and sepulchral chambers discovered since 1827 at Corneto, on the site of the ancient Tarquinii, at Vulci, Toscanella, Bomarzo, Cere, Val d'Asso, Orchia, and other places in the ancient Etruria. A brief description of these will be found under Etruscan Architecture.

Many of the tombs found in Lycia and other parts of Asia Minor have columns and entablatures to their façades wrought out of the solid rock. Some of the Lycian tombs, however, are upright insulated structures, either plain or decorated with pilasters and other ornaments, with roofs whose section is a pointed arch, after the fashion of some of the Indian monuments, owing to which they present a striking combination of Oriental and Grecian forms. Of sepulchres with temple-shaped façades there are two examples at Orchia, one of them a tetrastyle, the other a distyle in antis. Both partake of the Grecian Doric character, yet deviate from it greatly in two particulars: first, in the great height of the pediment; secondly, in the great width of the intercolumns. What now remains of the columns themselves is only sufficient to show their number and situation; yet that they were hewn out of the rock, like the entablature and pediment, scarcely admits of question. Of the magnificent sepulchre of Mausolus erected by Greek architects at Halicarnassus, an account is given under MAUSOLEUM.

Vitruvius says nothing on the subject of sepulchres and tombs, either Grecian or Roman; yet sepulchral edifices are still very numerous throughout Latium and Magna Græcia, and many of them must originally have been very conspicuous objects, and not a little remarkable on account of the studied architectural decoration bestowed on them externally: for besides subterraneous sepulchral chambers or vaults (which were usually very carefully finished internally, and not unfrequently ornamented with painting and stucco-work, and with marble or mosaic pavements), there is another and quite distinct class, consisting of structures raised above ground, insulated, and apparently solid. These may be described as generally of nearly cubical form, though some are of much loftier proportions. There are, besides, varieties of this class, in which either a conical or cylindrical superstructure is raised upon the square portion, which then becomes a basement; or else the superstructure is also square, but is distinguished from the lower part by pilasters, panels with inscriptions, and other architectural decorations: some of these have an upper sepulchral chamber, others a subterraneous one also, or one below the level of the ground.

What is called the "Sepolcro di Nerone," near Ponte Molle, may be taken as a specimen of the usual character of Roman tombs partaking of the cubic form. Like the generality of them, this is somewhat more than a perfect cube, the dimensions being 20 feet by 24 in height, or, including its covering, 27 feet. At each angle is a large acroterium presenting two quadrant-shaped surfaces, meeting at right angles at the external edge of two adjoining sides—a species of ornament almost peculiar to ancient altars and tombs. Of larger tombs of this class, there is one in the Via Portuensis, a double cube in height, the measurements being respectively 44 and 80 feet. In the example previously mentioned, the upper part is rather less in height than the basement, but here it is about a third more, and is also decorated with four pilasters on each front, with a small pediment, not supporting, but placed *between* the large acroteria at the angles. Of circular tombs we have a well-known example in that of Manutius Plancus at Gaeta, —a low circular tower (nearly solid within), about 60 feet in diameter, and 10 feet more in height; therefore, owing to its size, it is rather a mausoleum than a mere tomb. The same may be said of that of Cæcilia Metella at Rome; which structure, otherwise called Il Capo di Bove, from the ornaments in its Doric frieze, exceeds the one just mentioned in size, it being 90 feet in diameter, and its entire height about 130 feet. It does not, however, partake so much of the character of a mere tower as the tomb at Gaeta, because it consists of two nearly equal masses, namely, a square one with a cylindrical superstructure, and is therefore an example of that compound-form class which we have above pointed out. Among the tombs at Pompeii there is one which is circular in the upper part of its exterior, and internally has a dome of very peculiar shape, which does not show itself on the outside, but is cut out of the solid mass. Other sepulchral structures at Pompeii are very numerous, forming what is called the "Street of Tombs." Instead of cemeteries, or public burying-grounds, it was the custom in ancient Italy to erect tombs on each side of the principal roads leading from a city, as was the case with the Via Appia and others in the immediate vicinity of Rome.

The tombs of the middle ages are within buildings, churches, chantries, cloisters, &c., and exhibit almost every variety of form and enrichment, from the primitive stone coffin or Christian sarcophagus, to those lavishly decorated *catafalco* monuments which are so many piles of architecture and sculpture. Those of the first-mentioned kind are, for the most part, very little raised above the floor, and their upper surface is *en dos d'âne*, or forms a ridge-shaped lid. The next class consists of *Altar* or *Table Tombs*, comparatively plain, although with panelling or other architectural decoration on their sides. The next in order is the *Effigy Tomb*, first introduced in the 13th century, with a recumbent figure of the deceased upon it, extended, with the hands slightly raised, and joined as if in the attitude of prayer. Examples of this kind are very numerous, and highly interesting, both on account of their execution as works of sculpture and the information they afford in regard to the costume of the period.

Altar and effigy tombs were usually placed between the piers of an arch, or within a recess in a wall; and in either case the whole tomb was frequently covered by an arch forming a sort of canopy over it, of which kind is that of Aymer de Valence in Westminster Abbey (1334). In course of time this mode of architectural decoration came to be greatly extended. Instead of a single arch, three or more small arches were introduced, which, with the columns either supporting or placed between them, inclosed the figure on the tomb, giving the whole the appearance of a *shrine* or *screen*. Many of the French monuments of the period of the Renaissance are in this style of design, large and lofty insulated architectural masses, with a profusion of highly-enriched pilasters and arches, and numerous allegorical figures, beside other statutes and bas-reliefs, so that the *deposito*, or actual tomb, is the least portion of the entire composition.

In Italy there are many examples of what may be called *Façade* monuments, which are extensive architectural compositions, consisting of two or more orders of columns, with pediments, niches, statues, panels, and various other architectural decorations. Of such "*macchine colossali*," as Cicognara terms them, the monument of the doge Valier by Tirali, and that of the doge Pesaro by Longhena, may be quoted as instances. In both of them the figures are merely accompaniments to the architecture, and that which should be the principal is almost the most insignificant among them. In the Catafalc tomb, even when equally extravagant in point of accumulated embellishment, there is at least a certain degree of character that stamps it at first sight for what it is, whereas in those of the kind just referred to there is nothing to indicate a sepulchral monument. This last remark applies very forcibly to those two celebrated works of Michel Angelo, the tombs of Giuliano and Lorenzo de' Medici, each of which has, besides the figures of those personages, two naked semi-recumbent figures, a male and female, intended, or supposed to be intended, to express day and night (or sleep), and morning and evening. More becoming in feeling and in taste are many other Italian tombs of about the same period, which consist of little more than a simple *deposito*, or sarcophagus, with either a recumbent or semi-recumbent figure of the deceased upon it; such, for instance, as those of Giov. Andr. Boccaccio in the cloister of Santa Maria della Pace, and of Angelo Marzi in the church of the Annunziata at Florence. Although they have abandoned the architectural *caricatura* formerly in vogue for such purposes, instead of returning to the simple and natural expression of Christian monumental works, later sculptors have frequently given us allegorical compositions and groups of mythological figures, and the likeness of persons intended to be recorded is shown only in a medallion. In this vicious taste are many of the monuments in St. Paul's and Westminster Abbey, while others are chiefly remarkable for the fantastic conceits into which the artists have fallen, and which render them equally unbefitting the purpose they are designed for and the place where they are erected.

TOMBS, VAULTS, TOMBSTONES, TABLETS. In previous articles [COFFIN; INTERMENT] the various modes of disposing of the dead have been discussed; it is our intention here to show what rights the subjects of this country have, 1st, to burial, and 2ndly, to a permanent commemoration of themselves by means of monuments. It must be borne in mind that we treat here only of parish churches and churchyards, or of the parish burying-grounds subsidiary to the churchyard. The cemeteries which the necessities of an increasing population have caused to be established in the neighbourhood of many of our densely inhabited towns are private property, regulated at the pleasure of the proprietors.

By the 68th Canon of 1603 it is ordered that no minister shall refuse or delay, under pain of suspension by the bishop for three months, to bury any corpse that is brought to the church or churchyard (convenient warning being given him thereof before), in such form as is prescribed by the Book of Common Prayer, unless the deceased were excommunicated *majori excommunicatione*, and no man able to testify of his repentance. The Rubric further excludes from Christian burial those who have not been baptised or who have died by their own hands; and this latter class are defined to be such as have voluntarily killed themselves, being of sound mind, of which fact a coroner's jury are considered by ecclesiastical authorities to be the fitting judges. Thus the ecclesiastical law not only gives to the clergyman the right, but imposes on him the duty to bury, with only three exceptions, all who shall be brought within the precincts of his church. Nevertheless the ecclesiastical courts have admonished a minister and churchwardens to abstain from burying strangers in the churchyard, when the practice of doing so threatened to interfere with the rights of the parishioners; for the common law gives to the people the right of being buried within the churchyard of their own parishes: "Ubi decimas persolvebat vivus, sepeliatur mortuus;" and although the freehold of the churchyard, as of the church, is in the parson, he holds it only for the benefit of his parishioners, and subject to their right of interment in it.

This right of sepulture, however, applies only to the body: the Canon and the Rubric alike talk as though studiously of the "corpse" alone, never mentioning the coffin. In former times the use of coffins was confined to the richer classes, and these were often of stone or of other durable materials [COFFIN]; but the practice and no doubt the intention was that in the great majority of cases the process of decay, and, therefore, the occupation of the earth, should not be needlessly protracted. To use the words of Lord Stowell, "A common cemetery [by which he means a churchyard or parish burying-ground] is not *res unius ætatis*, the property of one generation now departed, but is likewise the common property of the living and of generations yet unborn, and is subject only to temporary occupations." On this doctrine are based the main points of the law concerning burials.

The establishment of churchyards is attributed to Cuthbert, archbishop of Canterbury, who in the year 750 introduced into this country the custom, then existing at Rome, of devoting an enclosed space round the sacred edifice to the interment of those who had been entitled to attend or had been in the habit of attending worship within its walls. Theretofore, notwithstanding a canon which forbade it (*De non sepeliendo in Ecclesiis*), the clergy interred persons of peculiar sanctity or importance within the walls of the church, especially in the side aisles of the nave, so as to remind the faithful of their example and of the duty of praying for their souls: and hence the rule that a body should not be buried in the church without the consent of the incumbent, he being supposed to be alone able to judge whether the deceased possessed the qualities which give him a title to that distinction. The churchyard was anciently held among the *res sacræ*, and no fees were taken for the use of it: nevertheless the payment of fees to the clergyman dates, in this country at least, from the Reformation, and the non-payment of those fees is held by the ecclesiastical courts a sufficient ground for the clergyman to withhold his offices, or at all events to prevent the erection of any monument or tablet for which he had previously given his consent; that consent being supposed to imply the payment of the usual or a stipulated fee. The churchwardens are also entitled to a fee for burials in the church, since on them falls the expense of repairing the pavement. It is even maintained that an incumbent is entitled to a fee upon the burial of his parishioner who has died in his parish and is removed for interment elsewhere. Sir H. Spelman preserves a vestry constitution of 1627 containing a table of fees for burial in the chancel, the nave, and the churchyard; the interments in the churchyard being differently charged as they were "coffined" or "uncoffined." These fees are not imposed at the discretion of the parson or of the parish; they are matter of ecclesiastical jurisdiction, and if they deviate from the amounts established by custom, must be approved by the ordinary after consulting the minister and the parishioners.

A vault cannot properly be made either in the church or churchyard, without the consent of the ordinary signified by a faculty, that is, a licence or permission, for that purpose; and this he does not grant until he has given the parson and parishioners an opportunity to express their opinions. A vault may be attached by prescription to a mansion; or again, the proprietors of a mansion may have a prescriptive right to be interred and to erect a tablet or tombstone in the aisle or chapel appurtenant to that mansion. But it would seem that the right adheres to the mansion, not to the family; who if they cease to be parishioners relinquish their right to the vault, the use of which may be granted to others. The heir, however, in this and in all cases may obtain an action of trespass at the common law against any one, even the parson or ordinary, who disturbs the remains, or removes or defaces the monument of his ancestor, or the hatchment, pennon, or coat armour suspended over his grave. In some parishes the parishioners have a prescriptive right to place a stone over a grave in the churchyard upon payment of a certain fee established by custom; but nothing of height can properly be erected without the consent of the ordinary; nor can a tomb or tombstone be repaired without the leave of the churchwardens; although the granting of that leave is a mere formality incumbent on those officers.

The placing of a monument in the church or a tablet on its walls is also within the jurisdiction of the ordinary; for the fixing of it in the chancel the consent of the rector is required, yet a lay rector has not a right to erect a monument or construct a vault there without a faculty from the ordinary. To remove without the ordinary's consent a monument or tablet once erected is an offence which subjects to prosecution before the ecclesiastical courts the party committing it, even though he should have himself erected the monument, and should have the consent of the incumbent for its removal.

As the erection of a tombstone, so the inscription upon it is a matter of ecclesiastical discipline, and an epitaph is unquestionably unlawful which is contrary to the canons or constitutions of the church in force at the time when the inscription is made. Thus when in a recent case the inscription "Pray for the soul of A. B." was objected to in the Ecclesiastical Court as recognising the doctrine of purgatory, the judge (whilst he deemed that prayers for the dead are not contrary to the canons, and, therefore, that the epitaph was not unlawful) distinctly affirmed the doctrine, that any new epitaph opposed to the doctrines of the Church of England might be removed, and the inscription of such an epitaph would subject the party who inscribed it to ecclesiastical censure.

(Haggard's *Consistory Reports*, i. 14, 205; ii. 333; Curteis's *Ecclesiastical Reports*, i. 880; Burn's *Ecclesiastical Law*, article 'Burial;' and Rogers's ditto.)

TON, or TUN. In modern English spelling the *ton* is a weight (twenty hundredweight, or 2240 pounds avoirdupois) and the *tun* is a measure of wine (two pipes, or 252 gallons). Accordingly, some have supposed that the measure was derived from the weight, and in fact a *tun* of water weighs about a *ton*. But a very little consideration of the manner in which *tonna* and *tunna* were used, is enough to convince any one that the weight was derived from the measure. These words are not classical, but they occur frequently in middle Latin (see Ducange, *in verb.*), and always as signifying a large cask. The hollow empty sound made by striking a large cask may have given rise to the name: we have often heard them say *ton* as plain as a cask can speak. The diminutive is *tonnella*, which was often used, but not much in England. The Commissioners of Weights and Measures found it only in Cardiganshire, standing for sixteen bushels of lime. The modern use of the word tunnel is now familiar enough. The old taxes of tonnage and poundage are enough to create a suspicion that the ton was originally a measure. This phrase would be tautology if tonnage meant a tax upon weight: we must understand tonnage and poundage to be a tax on measure and a tax on weight.

There are many local tons of weight which have sprung up in modern times.

TONE (in Music). The technical use of this word may be seen in Scale, Tetrachord, &c., in which it signifies a *musical interval*. In common language it refers to the *quality* of a musical sound, as when we speak of a fine-toned instrument.

In painting, the word tone is used in a somewhat similar manner. With reference to a particular tint it expresses the degree, quality, or intensity of a colour or shade, in relation to the other colours of the picture, or to the chiaroscuro. The tone of a picture, on the other hand, has relation to the general scale of colouring: thus a painting is said to be low, or gray, or warm in tone.

TONICS. [Analeptics.]

TONNAGE is the term for the capacity of burden possessed by a ship or other floating vessel. The amount of tonnage possessed by the United Kingdom is given under Trade and Shipping.

TONNAGE (or TUNNAGE) AND POUNDAGE. [Subsidy.]

TONSILS, DISEASES OF THE. [Quinsy.]

TONSURE (from the Latin, *tondere*, "to clip") is the name given to a distinguishing mark of the clergy of the Roman Catholic church, formed by cutting off a portion of the hair from the head. Mention is made of polled or shaven crowns in connection with the clerical character in the earliest ages of the church; but it seems to be clear that this has nothing to do with the modern tonsure: the practice of shaving the head or wearing the hair too short is in fact condemned in priests by Jerome and others of the Fathers. ('Bingham's 'Origines Ecclesiasticæ,' b. vi. c. iv. s. 16.) What is now called the tonsure was probably introduced not earlier than the latter part of the 5th century. Various explanations of its mystical meaning have been proposed: one theory is, that it is a sign of adoption by the church; another, that it is intended to symbolise the clerical subjection and obedience; another, that it is a memorial of the Saviour's crown of thorns, &c. According to the existing and long-established practice, the tonsure is formed by clipping away the hair from a circular space on the back of the head. The application of the scissors by the bishop to remove the first tuft is the initiatory rite by which persons are received into the clerical order. Of course the clerical crown, as it is called, must be preserved by repeated trimming when necessary; and the practice, we believe, is to enlarge it as the wearer rises in ecclesiastical station and dignity. The present however was not the universal form of the tonsure in former times. When the missionaries who had come over to Britain from Rome encountered in the 7th century the Scottish and Irish priests, they were horrified by observing that instead of a circular tonsure on the occiput, they were distinguished by a tonsure in the shape of a crescent on the forehead. The Roman missionaries asserted that this was the sort of tonsure worn by Simon Magus and his disciples. The true form of the tonsure and the proper mode of calculating Easter were the chief subjects of theological controversy in this island in the latter part of the 7th and the beginning of the 8th centuries.

TONTINE, a species of life annuity, so called from Lorenzo Tonti, a Neapolitan, with whom the scheme originated, and who introduced it into France, where the first tontine was opened in 1653. The subscribers were divided into ten classes, according to their ages, or were allowed to appoint nominees, who were so divided, and a proportionate annuity being assigned to each class, those who lived longest had the benefit of their survivorship, by the whole annuity being divided amongst the diminished number. The terms of this tontine may be seen in the French 'Encyclopédie' ('Finance' division, vol. iii). In 1689 a second tontine was opened in France. The last survivor was a widow, who, at the period of her death, at the age of 96, enjoyed an income of 73,500 livres for her original subscription of 300 livres. The last French tontine was opened in 1759. They had been found very onerous, and in 1763 the Council of State determined that this sort of financial operation should not be again adopted. Tontines have seldom been resorted to in England as a measure of finance. The last for which the government opened subscriptions was in 1789. The terms may be seen in Hamilton's 'Hist. Public Revenue.' A few private speculations have been entered into in the United Kingdom on the plan of the tontine.

TOPOGRAPHY (from the Greek *τοπογραφία*, which is from *τόπος*, "a place," and *γράφ,ειν*, "describe"). Perhaps the nearest corresponding combination of English words would be "place-description." The word topography is limited by usage to the description of cities, towns, villages, castles, churches, and other artificial structures, including notices of everything belonging to the places or connected with them; for instance, not only the site, construction of the streets, public buildings, &c., of cities and towns, but the number of inhabitants, trade, history, and so forth. The word occurs in the Greek writers. Cicero ('ad Attic.,' i. 13) uses *Topothesy* (*τοποθεσία*) as synonymous with topography, though topothesy should have a different meaning. In the Greek "topography" has a wider meaning than it has with us. But a description of a given place, with reference to its physical character, hardly comes within our notion of a topographical description, which is generally, at least, limited as above stated.

TOREUTIC. [Sculpture.]

TORMENTIL, *Tormentilla officinalis* (Smith), *erecta* (Linn.), a small perennial plant, growing in the whole of Europe and the north of Asia, in forests, bogs, and heaths. [Potentilla.] The root, or rather the rhizoma, is officinal. As the plant flowers in June and July, the best time to collect the rhizomata is in April and May. Those gathered in autumn, while they remain moist, are phosphorescent. The roots of the Tormentilla (Potentilla) reptans (Linn.), of the Potentilla Commarum, those of the common strawberry, of the Geum urbanum, and also of the Polygonum bistorta, are frequently confounded with those of the true tormentil—errors of no great importance as far as their medical employment is concerned, as they possess properties similar in kind, but inferior in degree. In Italy the root of the Geranium striatum is substituted for it.

The rhizomata of the genuine plant are large in proportion to the branches they bear. They lie obliquely in the earth; old ones are knotty or resemble knobs, from 1½ to 2 inches thick; younger ones are cylindrical, irregularly branched, the branches 1 to 2 inches long, and from one-fourth to one-half inch thick, curved and twisted. The epidermis and liber are very thin, but firm. The central part presents two or more concentric circles. The colour of the interior, when fresh, is a rose-red or fleshy colour; but when dried, it inclines more to a reddish or brownish yellow; in very old specimens it becomes white. It can be easily powdered: the powder is of a bright brownish-red. The rose-odour of the fresh root is lost by drying. Taste purely and strongly astringent. Specimens which are dark externally, and woody and white within, are to be rejected.

Water distilled from the fresh root has an agreeable rose-like odour. This plant contains more tannin than any other, except catechu and galls. Tormentil is the most powerful of our indigenous astringents, and more easily assimilated than oak-bark or galls. Though improper in active hæmorrhages, in passive discharges it is very useful, and may be given with aromatics, or opiates, or chalk, as in the compound powder of chalk. Few medicines are more efficacious for drying up the slimy mucus in which worms nestle in the intestines of children, than the compound powder of chalk. Infusion made with cold water is preferable to the decoction. The extract made in the common way soon spoils. But valuable as this substance is in medicine, it is of still greater utility in the arts and in agriculture. It may be most beneficially employed to tan leather, both where the oak grows and where it is absent, since one pound and a half of powdered tormentil is equal in strength to seven pounds of tan. It is used in Lapland and the Orkney Isles, both to tan and to dye leather, and in the latter parts to dye worsted yarn. By long boiling the tannin is converted into gum, and in times of scarcity the poor may collect and obtain much nourishment from the root. But the great service this plant renders in husbandry is its chief merit. Where it grows abundantly in wet pastures, the rot in the sheep is unknown. Where the heather has been burned on the Highland hills, this plant springs up spontaneously with the tender grass. [Anthelmintics.]

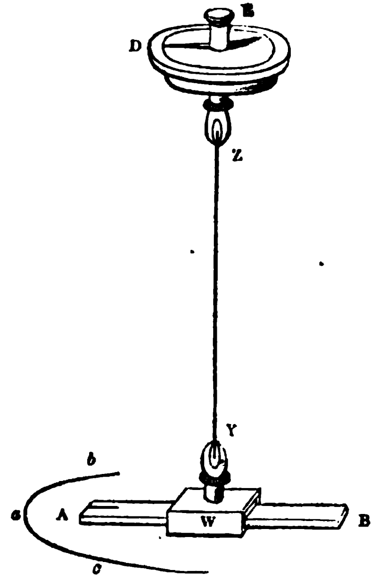
TORNADO. [Whirlwind.]

TORRICELLIAN VACUUM. [Barometer.]

TORRICELLI'S THEOREM. [Hydrodynamics.]

TORRID ZONE. [Zone.]

TORSION is that force with which a thread or wire returns to a state of rest when it has been twisted by being turned round on its axis: the thread or wire, which is suspended vertically, is attached at the upper extremity to some object, and at the lower extremity is a weight with a horizontal index, or a stirrup, which is to carry a needle or bar in a horizontal position.



Let z y be the wire, w the weight or stirrup, and a b an index or needle, and let *b a c* be part of a graduated ring on the same level as the needle; then, on turning the object w round till a mark on the extremity a of the index is brought to any point, *b*, on the ring, the wire becomes twisted; and when the power by which w is turned is removed, the elasticity of the wire causes the point at a to oscillate within the ring through an arc, as *b a c*, which continually diminishes till the index rests in its original position.

Under Elasticity is given an investigation from which it is proved that, while the force of torsion is moderate, its intensity is directly proportional to the angle or arc through which the extremity a of the index is moved in twisting the wire. It is also proved that t, the time of a complete oscillation, is constant, or that the vibrations are isochronous, like those of a pendulum which is acted upon by gravity; and further, that when a body, as w, is suspended, the squares of the times of vibration vary directly as the momentum of the body's inertia, and inversely as the force of torsion: consequently when the forms and weights of suspended bodies are the same, the force of torsion varies inversely with the square of the time. With respect to the effects which a variation in the length of the wire will cause in the force of torsion, it may be observed that in proportion as the lengths of the wires are increased, points at the lower extremities must be turned, about the axis, through greater arcs, in order to produce equal degrees of torsion at equal distances from the points of suspension; and hence, if the number of revolutions be equal, the force of torsion will be inversely proportional to the length of the wire: it follows therefore that the time of a vibration varies directly with the square-root of the length of the wire.

These deductions from theory are confirmed by their agreement with the results of the numerous experiments made by M. Coulomb with an apparatus similar to that which is represented above; the times in which a certain number of isochronous vibrations were made with wires of different lengths, and carrying at their lower extremities cylinders of different weights, being observed. By comparisons also of experiments on wires of the same length and of different diameters, consequently of different weights, Coulomb found that the times of vibration were inversely proportional to the weights, or to the squares of the diameters of the wires; and since the force of torsion varies inversely with the squares of the times, it follows that when the wires are of the like material and of equal lengths, the force of torsion varies directly with the fourth power of the diameter. M. Poisson, in a memoir on the equilibrium and movement of elastic bodies ('Mémoires de l'Académie des Sciences,' tom. viii.), has deduced the same law from purely theoretical considerations.

It may be convenient to compare the force of torsion with that of gravity, and for this purpose it will be necessary to observe merely that the time in which a pendulum, whose length is *l*, makes a complete oscillation in a very small arc is expressed by $\pi\left(\frac{l}{g}\right)^{\frac{1}{2}}$ [Pendulum], where *g* represents the force of gravity: then the time in which the torsion wire vibrates once on its axis being made equal to the time in which a simple pendulum vibrates, we have (using the formula in Elasticity), $\frac{\text{K}^2\text{M}}{n}=\frac{l}{g}$; therefore, as the momentum of inertia for a torsion wire suspending a body of a given form can be computed, and as *l* may be found from the observed time of a vibration, the value of *n* (the coefficient of the force of torsion) can be ascertained from this equation.

The torsion of slender wires was first employed by Coulomb for the purpose of determining the intensities of forces in nature and the laws of their action in circumstances which render direct methods inapplicable: his experiments were performed with an instrument which he invented, and which he designated a *torsion balance*. Under Electrometer is given a description of the instrument and of the method of employing it in finding the laws of electric attractions and repulsions; and it will, therefore, be sufficient in this place to explain its application in determining those of magnetic action. For this purpose Coulomb adapted to the suspending wire, which was of copper, a small stirrup, as w, also of copper, in which could be placed a magnetised needle of steel. Before this was done, however, a copper needle, equal in weight to the magnetised needle which was to be used in the experiment, was placed in the stirrup, and the plate d at the top of the glass case was turned round till one extremity of the copper needle, which turned with the plate, was brought to the zero of the graduations on the horizontal circle *b a c* in the case, the suspending wire being in an untwisted state: the whole case was afterwards turned round till the needle, still pointing to zero, was in the direction of the magnetic meridian, which had been previously determined. The copper needle was then taken away, and the magnetised needle put in the stirrup; and as soon as it was at rest in the magnetic meridian, the suspending wire was twisted by turning the stem e, to which it is attached at the upper extremity of the case, till the index there had passed over some given number of degrees, which in one experiment was 360°. The suspended needle was thus made to deviate from its previous position 10½ degrees, in which state the horizontal force of terrestrial magnetism was in equilibrio with the force of torsion; and the angle of torsion was then equal to 349½° (=360°—10½°). On turning the index at e through two revolutions, the needle was observed to rest between the opposing forces, at 21½° from its original place, when consequently the angle of torsion was $698\frac{3}{4}^\circ$ $(=720^\circ-21\frac{1}{4}^\circ)$. Obtaining in like manner several other angles of torsion with the corresponding deviations of the magnetic needle, and comparing them together, Coulomb found that the forces of torsion are constantly proportional to the sines of the deviations of the needle.

In order to discover the law of magnetic action with respect to the distances between the attracting or repelling bodies, Coulomb placed a magnetised needle in the stirrup of the balance, and after twisting the wire by turning the micrometer stem at E on its axis through a certain number of degrees, he observed where the needle rested between the opposing forces of torsion and the horizontal component of terrestrial magnetism: assuming then that the deviations of the needle were proportional to the forces of torsion, he found that, in order to make the needle deviate one degree, it was necessary to employ a force of torsion expressed by 35°. The wire being then untwisted, and the magnetised needle placed in the magnetic meridian, Coulomb introduced in the glass case, in a vertical position, and also in the plane of the magnetic meridian, a magnetised needle of the same dimensions as the other, so that if the two needles could have approached each other they would have been in contact at about an inch from the extremity of each; but the poles of the same denomination in the two needles being presented to each other, a repulsion took place, and the suspended needle came to a state of rest between the opposing forces of torsion and of magnetic repulsion. When the micrometer at E was allowed to remain in its actual position, the suspended needle was repelled 24 degrees, and consequently it was prevented from returning to the zero point by a force of torsion expressed by the sum of 24 degrees and of the horizontal force of terrestrial attraction $(=24\times 35^\circ$, or $840^\circ)$; thus the whole force of magnetic repulsion was expressed by 864°. In a second experiment, the wire being twisted by making the stem at E perform three revolutions $(=1080^\circ)$ in a direction contrary to that of the 24° before mentioned, the needle rested at 17° from zero: the force of magnetic repulsion was then expressed by the sum of 1097 degrees and the value of terrestrial attraction $(=17\times 35^\circ$, or $595^\circ)$, that is, in all, 1692 degrees. On comparing together several experiments of the same nature, and also several similar experiments in which the poles of a contrary denomination were presented to each other, Coloumb found, neglecting small differences which may be supposed to have arisen from the extent and configuration of the needles, that the forces of magnetic repulsion and attraction vary inversely as the squares of the distances.

The "bifilar magnetometer" which was invented by M. Gauss, is a species of torsion balance: it is described briefly in the article TERRESTRIAL MAGNETISM„ and at length in Taylor's 'Scientific Memoirs,' vol. ii. The apparatus with which, by the oscillations of two balls of lead at the extremities of a lever suspended horizontally by a string, Mr. Cavendish determined the average density of the earth, was also a balance acting on the same principle. [EARTH, MEAN DENSITY OF THE.] The bifilar suspension has also been claimed, apparently with justice, by Sir W. Snow Harris. See 'Rudimentary Magnetism,' parts i. and ii., p. 120, in which work, and also in the 'Rudimentary Electricity' of the same author, the various torsion instruments used in these branches of science are fully and satisfactorily described and illustrated.

For the strength of torsion in machinery, see MATERIALS, STRENGTH OF.

TORTOISE-SHELL. This beautiful substance, or at least the best kind of the material which goes under the name, is procured from a marine tortoise called the Hawk's-bill turtle, or *Testudo imbricata;* the Latin name being derived from the mode in which the scales upon the back are arranged, overlapping one another like the tiles upon the roof of a house, one kind of which were called by the Romans *imbrices.* In most other tortoises the several scales of which their covering is composed adhere to one another by their edges, like inlaid work. Each animal furnishes thirteen principal plates, five along the centre of the back, and four on each side; and twenty-five smaller scales or plates, which constitute the margin of the shell. The size and thickness of the plates depend on the magnitude and age of the animal, a fresh layer being produced every year; and at the margin of the large plates may be seen distinctly the edges of the layers as they thin off in succession. The horny plates are separated from the bony foundation by the application of heat; the whole shell being commonly placed over a fire until the plates begin to start from the bone, and the separation being completed by the aid of a slender knife. The shell varies much in value, being frequently injured by barnacles, limpets, and other shell-fish adhering to the turtles while alive, and interfering with the growth of the shell where they attach themselves. Occasionally plates of a uniform yellow colour are met with; and such are in great request among the Spanish ladies, who will give at least twice as much for a comb of plain tortoiseshell as for a mottled one. The belly-plates of the tortoise are yellow, and are sometimes found sufficiently clear for use.

Before working, the shell needs to be softened or *tempered,* which is usually done by dipping it for three or four minutes, or longer if it be very thick and brittle, in boiling water. Some manufacturers flatten and temper the shells with hot flat irons, similar to those used by laundresses; the tortoise-shell being, in the course of the operation, frequently dipped in cold water to prevent scorching. Generally, however, the less the shell is heated and pulled about the better, because from its apparent want of grain or fibre it is apt to become very brittle. Being also less fusible than horn, tortoise-shell cannot be made soft enough to be moulded without some injury to the colour; and accordingly the manufacturers, at least in England, never attempt to produce tortoise-shell combs with ornamental open work by means of dies. Such work is produced by pasting a piece of paper over the tortoise-shell, drawing the pattern upon it, cutting it out with drills and fine saws, and, after the paper has been removed by steeping in cold water, finishing the ornaments with the graver. The cutting or *parting* teeth of combs by machinery is described under COMB MANUFACTURE; but we may here notice another mode which is occasionally followed, and which illustrates the convenience arising from the flexibility of the material when warmed. A piece of tortoise-shell, large enough to make two combs, is bent or bowed in the direction of the length of the teeth, to such a degree of convexity that they may be cut with a straight bow-saw without cutting through either of the edges of the pieces of shell, which are required to form the top or back portions of the combs. The shell is then flattened and the ends or points of the teeth are separated with a narrow chisel or *pricker,* after which the combs are finished with files and scrapers, and bent to any required curvature upon wooden moulds. The frames for tortoise-shell eye-glasses are usually formed out of narrow slips of shell in which slits are cut with a saw, the slits being subsequently, while the shell is warm, *strained* or *pulled* open, until they form circular or oval apertures, by the insertion of tapering triblets of the required shape. The same yielding or flexible property is made use of in the manufacture of boxes; a round flat disc of shell being gradually forced by means of moulds into the form of a circular box with upright sides. The union of two or more pieces of shell may be effected by carefully scraping the parts that are to overlap, so as to render them perfectly free from grease, even such as might arise from being touched by the hand, softening them in hot water, pressing them together with hot flat tongs, and then plunging the joint into cold water.

In veneering with tortoise-shell, by which very beautiful work may be produced, it is usual to apply fish-glue, mixed with lamp-black, vermilion, green, chrome, white, or other colouring matter, at the back of the shell, both to heighten its effect and to conceal the glue or cement by which it is secured to the wooden foundation. In making knife-handles and some other ornamental work, metallic foils are put beneath the tortoise-shell veneer with excellent effect.

The qualities of tortoise-shell as brought to market are thus distinguished: Manilla, fine and large; Singapore, nearly as good as Manilla; West India, large and heavy, but red; Honduras, darker, but with large dark red spots; Calcutta, dark, heavy, and badly coloured; Bombay, the worst quality. Sometimes plates are obtained as large as 18 inches by 8 inches, and a quarter of an inch thick in the middle. The price of the best tortoise-shell is generally about 60s. per lb. A small import duty, formerly imposed, was repealed in 1846.

TORTURE, which in a legal sense means the application of bodily pain in order to force discoveries from witnesses, or confessions from persons accused of crimes, has been recognised by the laws of most civilised nations as an instrument for obtaining judicial truth. A learned civilian terms it "Mos antiquissimus, omnium feré bene institutorum populorum communis: ut non immeritó pro lege ac jure quodam gentium habeatur." (Wesenbechii, 'Paratitla ad Dig. de Quæstionibus,' num. 3.) Torture was applied to slaves at Athens (Demosthen., 'Orat. adv. Pantænet.'); and Cicero states that the Athenian and Rhodian laws allowed it to be applied even to citizens and freemen ('Oratoriæ Partit.,' 34); but there is some doubt as to the accuracy of this statement with respect to Athenian freemen. It has been questioned whether torture was used by the Romans during the republican period; but Cicero frequently speaks of it as an ancient practice, and attributes it to the customs and institutions of an earlier age ("moribus majorum"). ('Oratio pro Rege Deiotaro,' c. 1; 'Pro Milone,' c. 22; 'Orat. Partit.,' 34.) Tacitus also ascribes a modification of the practice to an ancient Senatus-consultum ('Ann.,' lib. ii., c. 30). However this may have been, it is beyond all doubt that the use of torture in judicial inquiries had become fully established in the time of the early emperors. Regularly the Roman law admitted the torture only in the case of slaves when examined either as witnesses or offenders; but under the emperors—even under Augustus, but more frequently under Tiberius and Caligula—instances occur in which freemen and citizens were interrogated by torture: most of these instances, however, are to be considered as irregular acts of power, not sanctioned by law. Rules regulating the mode of applying torture, and limiting the occasions of its application, were early established in the Roman law. One of the most important of these is that which Cicero in the passages above cited refers to ancient usage, namely, that a slave should not be tortured to give evidence against his master, except in the cases of incest and conspiracy. Tacitus says that in order to evade the operation of what he calls an ancient decree, prohibiting the "quæstio servi in caput domini," Tiberius, "novi juris repertor," invented the scheme of making over the slave from the accused to a public functionary, and then putting him to the torture against his former master. This device is however ascribed by other historians to Augustus. (Dion., lib. lv.) In judicial inquiries or public trials for crimes, the "quæstio" was applied at the instance of the accuser in the presence of the prætor and judices, and the statements made under torture were reduced into writing (in tabulas relata), and signed by the prætor (Heineccius, 'Ant. Rom.,' lib. iv., c. 18, sect. 25); but private persons also were permitted "in foro domestico" to extract evidence from their slaves by torture. (Cicero, 'Orat. pro Cluentio,' cc. 63, 66; Quintilian, 'Declam.,' 328, 338, 353.) At a later period of the Roman empire, many new regulations appeared, and the earlier restrictions upon this practice were wholly removed or greatly modified. Several exceptions to the rule, which prohibited "quæstiones in caput domini," were introduced, and even freemen were subjected to torture, when there was positive evidence of the "corpus delicti," and probable or presumptive evidence that the accused was the guilty person. Moreover, when the offence was of a grave character, and affected the head of the state immediately, personal exemptions from torture were not admitted. "Omnes omninó," says the 'Digest' (lib. xlviii., tit. 18; 'De Quæstionibus,' sect. 10), "in majestatis crimine, quod ad personas Principum attinet, cum res exiget, torquentur." (Wasserschleben, 'Historia Quæstionum per Tormenta apud Romanos,' Berol., 1836.)

It is remarkable, considering the extent to which the practice of torture was eventually carried by the Inquisition, that, according to the principles and early practice of the Canon law all severities of criminal justice were prohibited; and by the ancient decretals of the church, every ecclesiastical person who took part in them was liable to censure. Previous to the 13th century no trace of the use or permission of torture is to be found in the canon law, either in the process of accusation, which was founded entirely on the model of the Roman law, or in the inquiry. In the 13th century the severe rules of the Roman law respecting the torture of witnesses and accused persons "in crimine majestatis," began to be applied by the ecclesiastical law in the case of heresy, which was then considered and termed "crimen læsæ majestatis divinæ." Nevertheless, the earlier councils relating to the Inquisition, though violent in their denunciations against heretics, are silent respecting the use of torture; and the first trace of any ecclesiastical sanction of this mode of proceeding, even in the case of heresy or apostacy, is found in a decree of Innocent IV. in 1252, which, however, does not authorise the inquisitors to use it, but calls upon the civil magistrates to press offenders to confession against themselves and others by means of torture. At a subsequent period the necessity for secrecy in the proceedings of the Inquisition induced the use of torture by the inquisitors themselves, and the extent to which it was afterwards used is notorious. (Biener's 'Geschichte des Inquisitions-Processes.') An instance of the application of torture under the ecclesiastical law occurred in England, under remarkable circumstances, about sixty years after the first sanction of the practice by the Church of Rome. In the great contest between Clement V. and the Templars in 1310, inquisitors were appointed by the pope to examine the prisoners who were charged (among other offences) with apostacy and heresy. The Archbishop of York, who was one of the inquisitors, propounded to certain monasteries and divines several difficulties which had occurred to him respecting the mode of conducting the examinations. Among other questions he asked, whether they might make use of torture:—"Licet hoc in regno Angliæ nunquam visum fuerit vel auditum? Et si torquendi sunt, utrum per clericos vel laicos? Et dato, quód nullus omnino tortor inveniri valeat in Angliâ, utrúm pro tortoribus mittendum sit ad partes transmarinas?" (Hemingford, p. 256.) In consequence of the doubts of the archbishop, Edward II. refused to allow the inquisitors to torture the accused. Upon this Clement wrote a letter of remonstrance to the king, who referred the matter to the council; and upon their recommendation it was resolved that the Templars should in the first place be separately confined and examined singly; and if upon this mode of proceeding they refused to confess more than they had previously done, "quòd extunc *quæstionarentur*, ita quód quæstiones illæ illatæ fierent absque mutilatione et debilitatione perpetuâ alicujus membri, et sine violentâ sanguinis effusione." (Raynouard, 'Monumens Historiques relatifs à la Condamnation des Chevaliers du Temple.') In accordance with this resolution, a special commission from the king authorised the inquisitors "to dispose and deal with the bodies of the Templars in *quæstionibus* et aliis ad hoc convenientibus," as might seem fit to them to be done according to ecclesiastical law; and a precept was issued to the sheriffs of London, in whose custody the accused were, to suffer the inquisitors to examine them and put them to the torture. (Rymer's 'Fœdera,' tom. iii., pp. 228, 232.)

Judicial torture formed a part of all the legal systems of Europe which adopted the Roman law. In Germany it was gradually introduced as the use of the Roman law increased, and displaced the ancient Teutonic and feudal proceedings by ordeal and battle. Indeed, while these judicia dei continued in use, there is no notice of the existence of torture. In most German cities judicial torture was unknown until the end of the 14th century; although it appears in the statutes of the Italian municipalities at a much earlier period. (Mittermaier's 'Deutsche Strafverfahren,' theil i.) A species of torture was, indeed, employed in Germany to a very great extent during the middle ages, of which there are traces and traditions connected with the torture-chambers and instruments still exhibited in Nürnberg, Salzburg, Ratisbon, and other ancient cities and castles; but these were in general not used for legal or judicial torture, but for the proceedings of those secret religious tribunals, or 'Fehmgerichte,' which abounded at that period. The regular torture, however, as derived from the Roman law, continued in many European states until the middle of the last century, when more enlightened views on the subject of jurisprudence led to a prevailing conviction of the inefficacy and injustice of this mode of ascertaining truth. In France the "question préparatoire" was discontinued in 1780 by a remarkable decree, which is to be found in Merlin's 'Répertoire,' vol. x.; and torture in general was abolished throughout the French dominions at the revolution in 1789. In Russia its abolition, though recommended by the Empress Catherine in 1763, was not effected until 1801. In Austria, Prussia, and Saxony it was suspended soon after the middle of the last century; but although so seldom used as to be practically extinct, torture continued to form part of the laws of Bavaria, Hanover, and some of the smaller states of Germany within the last sixty years. (Mittermaier's 'Deutsche Strafverfahren,' theil i.) In Scotland, where the law is almost wholly founded upon the civil law, the use of torture prevailed until the reign of Queen Anne, when it was declared by the act for improving the union of the two kingdoms (7 Anne, c. 21, s. 5), that in future "no person accused of any crime in Scotland shall be subject or liable to any torture."

The history of the use of torture in England is curious. From the hesitation to apply it to the Templars in the reign of Edward II. (1310), as above mentioned, as well as from the express statement of Walter de Hemingford, it appears to have been at that time unknown in England, either as an act of prerogative, or as an instrument of criminal inquiry warranted by law. Nevertheless, Holinshed relates that, in 1468, Sir Thomas Coke, the lord mayor of London, was convicted of misprision of treason upon the evidence of one Hawkins, given under torture; and that Hawkins himself was convicted of treason by his own confession on the rack, and executed. From this period until the Commonwealth the practice of torture was frequent and uninterrupted, the particular instances being recorded in the council-books, and the torture-warrants in many cases being still in existence. The last instance on record occurred in 1640, when one Archer, a glover, who was supposed to have been concerned in the riotous attack upon Archbishop Laud's palace at Lambeth, "was racked in the Tower," as a contemporary letter states, "to make him confess his companions." A copy of the warrant under the privy seal, authorising the torture in this case, is extant at the State-Paper Office. With this instance the practice of torture in England ceased, no trace of its continuance being discernible during the Commonwealth or after the Restoration. But although the practice continued during the two centuries immediately before the Commonwealth without intermission, it was condemned as contrary to the law of England, and even declared to be unknown in this country by judges and legal writers of the highest character who flourished within that period. Thus Fortescue, who was chief-justice of the court of King's Bench, and wrote his book, 'De Laudibus Legum Angliæ,' in the reign of Henry VI., and who notices a case of false accusation under torture (which was probably the case of Sir Thomas Coke above mentioned), condemns the practice in the strongest terms, though he does not expressly deny its existence in England. (Fortescue, cap. 22.) Again, Sir Thomas Smith, a very eminent lawyer, statesman, and scholar, who wrote in the early part of Elizabeth's reign, says that "torment or question, which is used by the order of the civil law and custom of other countries, is not used in England. It is taken for servile." (Smith's 'Commonwealth of England,' book ii., cap. 27.) And Sir Edward Coke, who wrote in the reign of James I., says "there is no law to warrant tortures in this land; and there is no one opinion in our books, or judicial record, for the maintenance of them." (3 'Inst.,' 35.) Notwithstanding this explicit denunciation of the practice as against law, both Smith and Coke repeatedly acted as commissioners for interrogating prisoners by torture (Jardine's 'Reading on the use of Torture in England'); and the latter, in a passage which occurs in the same book, and only a few pages before the words just cited (p. 25), impliedly admits that torture was used at examinations taken before trial, though it was not applied at the arraignment or before the judge. There is also a direct judicial opinion against the lawfulness of torture in England. In 1628, the judges unanimously resolved, in answer to a question propounded to them by the king in the case of Felton, who had stabbed the Duke of Buckingham, "that he ought not to be tortured by the rack, for no such punishment is known or allowed by our law." (Rushworth's 'Collections,' vol. i., p. 638.) And yet several of the judges who joined in this resolution had themselves executed the warrants for torture when they held ministerial offices under the crown. Possibly the explanation of this inconsistency between the opinions of lawyers and the practice may be found in a distinction between prerogative and law, which was better understood two centuries ago than it is at the present day. It was true, as the above authorities declared, that torture was not part of the common law; it was not used in judicature, as it was by the Roman law and the legal systems derived from it in Germany, Italy, and Spain; and, therefore, in England no judge could by law direct the torture to be applied, and no party or prosecutor could demand it as a right. But that which was not lawful in the ordinary course of justice was often lawful for the prerogative of the crown, which authorised this mode of enforcing the discovery of crimes affecting the state, such as treason or sedition, and sometimes of offences of a grave character not political,—acting in this respect independently of, and even paramount to, the common law, in accordance with the doctrine asserted so early as the reign of Edward I., "quod Rex pro communi utilitate per prerogativam suam in multis casibus est suprà leges et consuetudines in regno suo usitatas." ('Rolls of Parliament,' 20 Edw. I., A.D. 1292, vol. i.) This view of the subject is confirmed by the circumstance that in all instances of the application of torture in England, the warrants were issued immediately by the king, or by the privy council. Objectionable as the use of torture was in all countries and under all circumstances, it was in no country so unjust and dangerous an instrument of power as in England. In other countries, where it formed part of the law of the land, it was subject to specific rules and restrictions, fixed and determined by the same law which authorised the use of such an instrument, and those who transgressed them were liable to severe punishment. But in England there were no rules, no responsibility, no law beyond the will of the king. "The rack," says Selden, "is nowhere used as in England. In other countries it is used in judicature when there is *semiplena probatio*—a half-proof against a man; then, to see if they can make it full, they rack him if he will not confess. But here in England they take a man and rack him—I do not know why nor when—not in time of judicature, but when somebody bids." ('Table-Talk,'—Trial.)

The particular modes of applying torture were as various as the ingenuity of man is fertile in devising the means of inflicting bodily pain. Cicero and other Roman writers speak of the *equuleus*, or *eculeus*, and the *fidiculæ*, as common instruments of torture; but it is extremely doubtful what they were. Much discussion respecting them, and a reference to the various authors who have mentioned them, will be found in a treatise entitled 'Hieronymi Magii Anglarensis de Equuleo Liber Posthumus,' Amsterdam, 1664. The rack, which was common throughout Europe, was a large frame, in shape somewhat resembling a mangle, upon which the examinant was stretched and bound; cords were then attached to his extremities, and, by a lever, gradually strained, till, when carried to its utmost severity, the operation dislocated the joints of the wrists and ankles. This engine is said to have been brought into the Tower by the Duke of Exeter in the reign of Henry VI., and was thence called the Duke of Exeter's daughter. (3 'Inst.,' 35.) Besides the rack there were endless varieties of what were termed the "lesser tortures," such as thumb-screws, pincers, and manacles. In England, one of the most dreaded engines of this kind was the scavenger's daughter, so called by a popular corruption from Skevington's daughter, being invented by Sir William Skevington, a lieutenant in the Tower in the reign of Henry VIII. (Tanner's 'Societas Europæa.') In Scotland the instruments were the boots, called in France "le brodequin" (in which the torture was applied by driving in wedges with a hammer between the flesh and iron rings drawn tightly upon the legs); the thummikins; the pinniewinks, or pilliewinks; the caspitaws, or caspicaws; and the tosots. (Maclaurin's 'Introduction to Criminal Trials,' sect. 9.) The particular construction of these barbarous instruments it would be difficult at the present day to ascertain, but several of them were in practical use in Scotland within twenty years from the final abolition of torture in that country in 1708. (Howell's 'State Trials,' vol. vi.)

It is remarkable that although the use of torture in judicature has prevailed in most civilised countries, it has been almost universally denounced by enlightened jurists of all ages. Cicero repeatedly condemns it as unjust and inefficacious; and even the civil law, which sanctioned the practice in Europe for many centuries, speaks of it as "a deceitful and dangerous instrument, which very often fails to extract the truth." ('Dig.,' lib. xlviii., tit. 18.) The opinions of eminent lawyers in England have been already cited; and the juridical writers of the Continent, in more recent times, have unanimously taken the same view of the subject. (Mittermaier's 'Deutsche Strafverfahren, theil i.) On the other hand, a curious defence of torture will be found in Wiseman's 'Law of Laws, or the Excellence of the Civil Law.'

TORUS. [MOULDINGS.]

TORY. This name has now, for about two hundred years, served to designate one of two principal political parties in this country. It is not to be expected that for so long a time the name has been always associated with one uniform set of political principles, or that any formula could be devised which would accurately describe Toryism at every period of its history. Extending, like the name of the other principal political party, from the legislature through every class of the community, it would naturally, where the number of persons to be brought to concur in any change is so large, preserve any meaning which it has once acquired for a length of time, and throughout perhaps a general consistency of meaning; but on the other hand, engaged as the Whig and Tory parties of the legislature have been without intermission in a struggle for power, which power is attended by profit, they have been always exposed to the temptation, from whose insensible workings even the best disposed men are not secure, of altering and adapting opinions so as to facilitate the gaining what they fight for, or the keeping what they have gained; and the far more numerous members of the party who are without the legislature would generally follow those whom they look upon as their leaders, and by whose success every adherent of the party has some hope of being benefited.

The name Tory, as well as the name Whig, and the existence of two parties in the state corresponding to those which have now been known for a long time as Whig and Tory parties, date from the reign of Charles II. "It was in the year 1679," says Mr. Hallam, "that the words Whig and Tory were first heard in their application to English factions; and though as senseless as any cant terms that could be devised, they became instantly as familiar in use as they have since continued. There were then indeed questions in agitation which rendered the distinction more broad and intelligible than it has generally been in later times. One of these, and the most important, was the Bill of Exclusion, in which, as it was usually debated, the republican principle, that all positive institutions of society are in order to the general good, came into collision with that of monarchy, which rests on the maintenance of a royal line, as either the end or at least the necessary means of lawful government. But as the exclusion was confessedly among those extraordinary measures to which men of Tory principles are sometimes compelled to resort in great emergencies, and which no rational Whig espouses at any other time, we shall better perhaps discern the formation of these grand political sects in the petition for the sitting of parliament, and in the counter addresses of the opposite party." ('Constitutional History of England,' vol. ii. p. 592.) The first Tories opposed the Exclusion Bill and supported Charles II. in his endeavour to prevent a renewal of the attack upon his brother, by successive prorogations of the parliament. The origin of the name is referred by Roger North, a very hot Tory, in a curious passage, to the connection of the party with the Duke of York and his popish allies. "The Exclusioners," he says, "observing that the Duke favoured Irishmen, all his friends, or those accounted such by appearing against the Exclusion, were straight become Irish; thence Bogtrotters, and in the *copia* of the factious language the word Tory was entertained, which signified the most despicable savages among the wild Irish; and being a vocal clear-sounding word, readily pronounced, it kept its hold, and took possession of the foul mouths of the faction, and everywhere as these men passed we could observe them breathe little else but Tory." ('Examen,' p. 321.) Thus Dr. Johnson's first interpretation of *Tory* in his Dictionary is, "A cant term, derived, I suppose, from an Irish word signifying a savage;" and Mr. Moore, in his 'Memoirs of Captain Rock,' sarcastically refers the history of the Tory party to a general 'History of the Irish Rogues and Rapparees.' Dr. Johnson proceeds to give an explanation of the word *Tory*, which is perhaps as good a short general description of the principles of Toryism as is to be given:—"One who adheres to the ancient constitution of the state, and the apostolical hierarchy of the Church of England." In other words, the maintenance of things as they have been, or, when some great change has taken place against the will of this party, things as they are, has from the beginning been the prime characteristic of Toryism. The term, as indicating an existing party, is now nearly obsolete; no party, and few individuals, would choose to designate itself or themselves as Tory.

The history of the Tory party, rising and falling in the state, may be traced in a series of articles in Knight's 'Companion to the Newspaper' for 1834, 1835, and 1836, entitled 'Changes of Administration and History of Parties;' or in Mr. G. W. Cooke's 'History of Party,' 3 vols. 8vo, which is on the whole a useful publication, though its accuracy is not to be implicitly depended on.

TOURBINE. [TURBINE.]

TOURN. [LEET.]

TOURNAMENT, or TOURNEY, is from the French *tournoi*, formerly *tournoiement*, for which the Latin writers of the middle ages use *torneamentum*, *tornamentum*, or *turneimentum*, and sometimes also *torna*, *torne*, *tornatio*, *tornerium*, or *torneta*. The Byzantine annalists have transferred the word into *ternementum* (Τερνεμεντον). There can be little doubt, though other etymologies have been suggested, that *tournoiement* means merely a turning or wheeling about, from the common French verb *tourner*, to turn. This will agree with other tourns. We have in England the sheriff's turn or tourn. Other barbarous Latin words of the same connection are *tornare*, to turn about in fight, and also to call out or challenge to combat (in which last sense there is also the old French lui tourner (or torner), par gage de bataille); *torneare*, *torniare*, *turneare* (in French *tournoier*), *torniamentare*, and *torneizare*, to take part in a tournament; *torniator*, a performer in a tournament. (Du Cange, 'Glossarium ad Scriptores Med. et Inf. Latinit.,' vi.; Carpentier, 'Glossarium Novum,' iii.; H. Spelman, 'Glossarium Archaiologicum;' Fr. Junii, 'Etymologicum Anglicanum,' ad vv. *Tourneying* and *Tournoy*.)

A tournament may be defined to have been a species of combat in which the parties engaged for the purpose of exercising and exhibiting their courage, prowess, and skill in arms, and not either out of enmity (as in ordinary warfare), or even (as in the modern duel) for the mere purpose of wiping off some dishonourable imputation (a purpose which was served rather by the ancient ordeal or wager of battle than by the tournament). It is obvious, however, that although the primary and professed design of the tournament was nothing more than to furnish an exciting show, and to give valour and military talent an opportunity of acquiring distinction, other passions would be very apt to intermingle in the heat of contest with the mere ambition of superiority, and sometimes even to disguise themselves under that pretext.

The origin of the tournament has been carried back at least to the Roman times. Virgil's description of the game of Troy (*ludus Trojæ*, Æn. v. 545–602) is, in some passages, not unlike what the name would lead us to suppose the tournament may have originally been. The tournament, like the other customs of chivalry, must be properly considered to have taken its rise after the establishment of the feudal system. Some writers attribute the invention of the tournament to the Emperor Henry, surnamed the Fowler, who died in 936; and another common account, given on the authority of the Chronicle of Tours, and the Chronicle of St. Martin of Tours, is that its inventor was Geoffrey of Preuilly, ancestor of the counts of Anjou, who died in 1066; but Du Cange, in his Dissertations 'De l'Origine et de l'Usage des Tournois,' at the end of his edition of Joinville, quotes various notices of tournaments held before the age of either of these personages: among others, one which took place at the celebrated interview between Louis of Germany and Charles the Bald of France, at Strasburg, in 841, as mentioned by the contemporary chronicler Nithard. Geoffrey of Preuilly perhaps introduced the tournament into Western France. From the French it appears to have passed to the English and the Germans, and, in a later age, to the Italians and the Greeks. Tournaments are said to have been first practised by the English in the time of Stephen; but they were forbidden by Henry II., as they had already been by the church; and it was not till the reign of Richard Cœur-de-Lion that they were properly established in this country. The flourishing era of the tournament, here as well as in France and elsewhere, was in the 13th and 14th centuries; but it continued in frequent use down to the middle of the 16th, and was not altogether abandoned till a considerably later date, although the few tournaments that were held in the latter part of that century were rather such mere shows or spectacles as have been sometimes exhibited under the same name even in our own day, than the real combats which were so called in an earlier age. The accident of Henry II. of France meeting his death at a tournament in 1559 almost at once occasioned the cessation of the practice everywhere as well as in France; but the spirit by which it was formerly kept up had long before this been decaying under the influence of the various circumstances which, at least from the middle of the preceding century, had been operating a general change in the social condition of Europe. Among the physical causes in question the chief may be considered to have been the introduction of fire-arms into war; among the moral, the extension of the commercial spirit, and the rise everywhere of a new literature, together bringing with them other habits, other tastes, another civilisation. The Church of Rome, however, it may be observed, which had set its face very stoutly against tournaments from about the middle of the 12th to the middle of the 13th century, prohibiting persons from engaging in them by some of its decrees on pain of excommunication, and denying Christian burial to such as lost their lives in these contests, had long been reconciled to them, and for some ages had rather cherished and encouraged the practice than otherwise.

Tournaments were usually held on the invitation of some prince, which was proclaimed by his heralds throughout his own dominions, and at all the foreign courts or other places whence it was expected or desired that parties might come to take part in the martial competition. A detail of the forms and ceremonies that were observed in fixing the lists (or boundaries within which the fighting was to take place), in offering and accepting the challenges, in declaring the issue of each encounter, and in assigning and bestowing the prizes (which last office was often performed by female hands), cannot be attempted here. All these particulars, together with the usual laws or regulations of the combat, and the mode of fighting (which was commonly with lances and swords, and in the first instance always on horseback, although parties who were dismounted frequently continued the contest on foot), may be most conveniently learned from the many accounts of tournaments in Froissart and other old chroniclers, or even from such fictitious narratives as the 'Knight's Tale of Palamon and Arcite,' in Chaucer (or Dryden's paraphrase of it), or that of the tournament at Ashby in Scott's 'Ivanhoe,' or from Scott in his 'Essay on Chivalry' ('Miscellaneous Prose Works').

The distinction between a tournament and a joust, or just, is not very clear. Du Cange makes the joust to be properly a single combat or duel, whereas in a tournament a considerable number of combatants were commonly engaged on each side. But this distinction is certainly not generally observed in the use of the two words; and our English archæologist, Spelman, who defines *torniare,* "gladiis concutere, *justas facere,* hastitudium exercere," does not appear to have been aware of it. The term jouste or joust has been derived, improbably enough, from the Latin *juxta,* "near to," because, say the etymologists, the combatants here fought hand to hand. It is, no doubt, connected with the verb to justle, or jostle (in French, *jouster*), though possibly the original word may be best preserved in the Italian form *giostra,* which the Byzantine writers have imitated in their *τζουστρα* and *τζουστρια.* There was also the species of single combat termed a *pas d'armes,* or passage of arms: it was at a *pas d'armes* that Henry II. was killed. On this subject, besides the works quoted above, the reader may consult the 'Traité des Tournois, Joustes, Carrousels, et autres spectacles publics' (par Claude François Menestrier), 4to, Lyon, 1669; and 'Mémoires sur l'ancienne Chevalerie, considérée comme un Etablissement politique et militaire,' par J. B. de la Curne de St. Palaye, 3 tom. 12mo, Paris, 1759–1781.

TOURNIQUET is a peculiar kind of bandage applied to a limb for the purpose of arresting the current of blood through its main artery. It is employed for this purpose in several cases, but especially in amputations of parts of the limbs, where large arteries have to be suddenly cut across. Before the invention of the tourniquet, surgeons used to constrict the limb with a simple tight bandage; but although this plan may well be resorted to in an emergency, it not only produces excessive pain, but, by obstructing the current through the veins more than that through tho arteries, produces an extreme engorgement of the limb, and in amputation permits severe hæmorrhage. A slight improvement in this plan was that of twisting pieces of wood under the band, and so gradually tightening it; but the first instrument formed on the principles of the tourniquet was invented by Jean Louis Petit in 1718. Since that time various changes have been introduced, but at present the construction of all tourniquets is nearly similar. They consist of a very tough band, about an inch and a half wide, upon which there is a moveable leather pad, to be placed immediately over the artery on which it is desirable that the chief pressure should be applied. For this purpose, also, the surface of the pad must be directed towards the bone of the limb, that the artery may be pressed firmly against it. The rest of the band is passed round the limb, and is fastened by a buckle. It is tightened and loosened by means of a bridge of brass, which is capable of being elevated or let down by a screw passing through it, and at the ends of which there are two small rollers, around each of which the band is made to take a half turn. In use, the bridge and screw are placed on the opposite side of the limb to the pad.

The tourniquet is now not so generally used as formerly. Many surgeons prefer to have the artery compressed during an amputation by an assistant, because the tourniquet is not free from the objection of compressing the veins as well as the artery, and is liable to accidents which cannot be instantly repaired. An instrument of a superior character has also been invented by Signor Signoroni, a surgeon at Milan. It is composed of two arches of steel, connected by a hinge at one end, and each bearing at the other end a pad. By an Archimedes screw ingeniously placed at the hinge, the pads can be approximated and separated like the ends of the blades of a pair of callippers, and can be immoveably fixed in any position. In use, one pad is put over the artery, and the other on the opposite part of the limb, and the screw is worked till, in their tendency to approximate, the pads have sufficiently compressed the artery, upon which alone the pressure is thus made to fall.

As already said, in an emergency, such as that of a wound of any of the large arteries of a limb, when medical aid is not near, the old-fashioned tourniquet should be instantly applied. A piece of strong tape or cord should be tied in a double knot round the limb above the wound; a piece of wood, or anything firm, should be then passed under it, and twisted, just as packers tighten the cords round bales and boxes, till the flow of blood has ceased. For hæmorrhage from large veins or small arteries, this tourniquet should not be employed, but simple pressure with the finger or the hand.

TOWN, in its popular sense, is a large assemblage of adjoining or nearly adjoining houses, to which a market is usually incident. Formerly a wall seems to have been considered necessary to constitute a town; and the derivation of the word, in its Anglo-Saxon form "tun," is usually referred to the verb "tinan," to shut or enclose. In legal language "town" corresponds with the Norman "vill," by which latter term it is frequently spoken of in order to distinguish it from the word town in its popular sense. A vill or town is a subdivision of a county, as a parish is part or subdivision of a diocese; the vill, the civil district, being usually co-extensive with the parish, the ecclesiastical district, and, *primâ facie,* every parish is a vill, and every vill a parish. Many towns however, not only in the popular, but in the legal sense of the term, contain several parishes, and many parishes, particularly in the north of England, where the parishes are exceedingly large, contain several vills, which vills are usually called tithings or townships. As until the contrary is shown the law presumes towns (or vills) and parishes to be co-extensive, Lord Coke goes so far as to say that it cannot be in law a vill unless it hath, or in times past hath had, a church, and celebration of divine service, sacraments, and burials. But this, for which no authority is given, appears to confound parish and vill, and to be inconsistent with the cases in which it has been held that a parish may consist of several vills. (1 Lord Raymond, 22.) The test proposed by Lord Holt is, that a vill must have a constable, and that otherwise the place is only a hamlet, an assemblage of houses having no specific legal character. Hence a vill is sometimes called a *constablewick.* Towns are divided into cities, boroughs, and upland towns, or (as we should now call them) country towns. Towns belonging to the last of these classes have been described as places which, though enclosed, are not governed, as cities and boroughs are, by their own elected officers. The Anglo-Saxon "tun" terminates the names of an immense number of places in England; and in the southern counties the farm *enclosure* in which the homestead stands is usually called the barton (barn-*town*), in Law Latin, bertona.

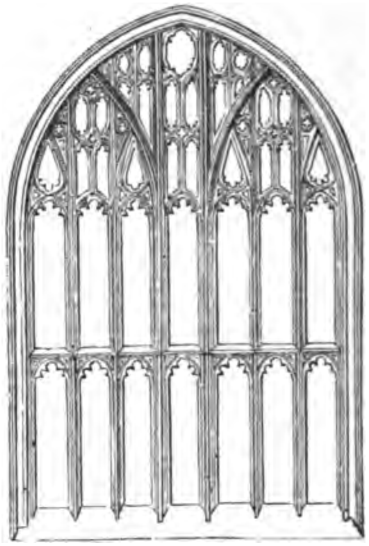
TOWNLEY MARBLES, the name of an assemblage of Greek and Roman sculpture which now forms a portion of the extensive collection of antiquities in the British Museum. It received its appellation from Charles Townley, Esq., of Townley in Lancashire, who began forming this collection whilst residing in Rome between 1765 and 1772, a period when excavations on the sites of ancient edifices were eagerly prosecuted. Mr. Townley was a Roman Catholic, educated on the

Continent, and, being well connected, was in friendly relations with the papal authorities, and was at the same time in intimate association with Winckelmann, Gavin Hamilton, and other distinguished artists and archæologists then resident in Rome, and who readily afforded their advice and assistance in his purchases. Thus aided, he succeeded whilst at Rome in bringing together a very choice collection of ancient marbles, bronzes, terra-cottas, gems, &c.; and after his return to England he continued to add to it by means of agents at Rome, who kept him apprised of any really valuable works which were brought to light and open to purchase, as well as by the purchase of the collection previously formed by Nollekens, the sculptor, and any desirable specimens offered for sale in this country. After Mr. Townley's death, in January, 1805, his executors, in accordance with the terms of his will, offered his collection of terra-cottas and marbles to the nation. The government accepted the offer, and a vote of 20,000*l.* was obtained for the purchase. The bronzes, coins, and gems were subsequently (1814) purchased for 8200*l.* The purchase of the Townley marbles rendered necessary the erection of a suite of rooms to contain these and the previously acquired works of ancient art, and led to the creation of a new department under the title of the Department of Antiquities. The collection was opened to the public in 1807, and was called the Townley Gallery; but since the rooms originally built for the collection have been swept away to make room for the present structure, the Townley marbles have been incorporated with the general collection of Græco-Roman remains, or "works discovered in Italy, but owing their origin and character, either directly or mediately, to the Greek schools of sculpture." Of these works which fill the Græco-Roman galleries in the British Museum, the Townley collection forms the most important portion, both as regards extent and character. It would be out of place to particularise here the specimens of a collection which is now incorporated in the national collection, but we may mention that among the statues belonging to it are the exquisite Aphrodite, or Dione (given in this work under Dione); the Discobolus (the finest of its kind extant, engraved under Discobolus); the well-known Drunken Faun; a fine bronze Heracles [Heracles], a Fortune, and several more of a very high character: that among the rilievi are, Achilles; the Muses; the singularly graceful Bacchante, and various Dionysiac groups, given under Dionysia; and that the busts include some of the noblest character, including an early Heracles; the Hera, given under that name; others of Athene, Zeus, Apollo, and other of the Olympian deities; the terminal Pan; the very beautiful female head rising from the petals of a water-lily or lotus, known as the Clytae; the majestic Homer; with others of the finest of the Græco-Roman period, and many of Roman date. There are besides some very fine sculptured vases, sepulchral urns, cippi, altars, &c., in the Græco-Roman rooms, as well as the terra-cottas which formed a part of the original Townley collection. A full account of the Townley Marbles will be found in the two volumes published under that title in the 'Library of Entertaining Knowledge.'

TOWNSHIP. This term is sometimes used to denote the inhabitants of a town in their collective capacity. In legal signification it is a vill forming part of a parish in cases where a parish has been divided for secular purposes into several vills or townships.

TRACERY, in architecture, a term of uncertain origin, and almost peculiar to our own architectural vocabulary, there being no corresponding term in any other language to denote with equal brevity and clearness that species of pattern-work formed or *traced* in the head of a Gothic window by the mullions [Mullion] being there continued, but diverging into arches, curves, and flowing lines, enriched with foliations. The term is also applied to ornamental design of the same character, whether for doors, panelling, or ceilings; the only difference being that in windows the pattern or tracery is perforated, and in other cases closed, that is, is a mere pattern carved on the surface of a solid part; except in particular instances, where the tracery on parapets, battlements, turrets, spires, &c., is pierced, and then it is described as *open-work*. The latter term necessarily implies tracery of some kind or other, though "tracery" does not imply "open-work," the latter being merely an exception from the usual mode.

Much both of the beauty and character of the Gothic or Pointed style depends upon windows and their tracery; and it is one great and peculiar merit of the style, that such indispensable apertures for the admission of light are made to constitute some of its most striking features, and to exhibit very forcibly the pervading principle of the entire system. On referring to Gothic Architecture, col. 440, it will be seen that tracery does not occur in the First Pointed or Early English style, for there the windows consist merely of so many single apertures, placed side by side, and united only by their external mouldings, instead of being included within a larger arch. The first principle followed was therefore rather of *addition* than of *combination;* but as soon as the latter idea was adopted, it necessarily led to the continuation of the window by perforating the *tympanum*, or space between the smaller arches and the larger one over them. At first this was usually done by filling up the *head* of the window with a single circle cut into foils, and with the open spandrels or smaller triangular spaces so produced. Of such windows an example from Westminster Abbey is shown in the column above referred to, and in the following columns are other instances where tracery of the same character becomes more elaborate and complicated, either by the circle being repeated, as in the example from York, or subdivided into smaller ornamental compartments, as in that from Exeter. This species of tracery has been very inappropriately distinguished by the name of *Geometrical*, while that which succeeded it is termed *Flowing* from its being composed throughout of curved lines interwoven with each other, after the manner of the example from Kirton, which is shown along with the others above mentioned. In Third Pointed or Perpendicular tracery, on the contrary, the lines of the mullions are continued in the head of the window, and divide it into panels, which are in turn subdivided into smaller ones. The annexed is a specimen of such window, from St. Mary's Church, Oxford.



What is called *Flamboyant* tracery is a species of the *Flowing* tracery peculiar to French Gothic, and is remarkable not only for its richness and intricacy, but for its irregularity, the pattern of the separate compartments not being perfectly symmetrical, although one half of the window corresponds with the other. To the above-mentioned varieties may be added another peculiar to Germany, but not very common there; this has obtained the name of *Stump tracery*, in consequence of some of the mouldings appearing to be broken off, and leaving only short ends or stumps where they intersect other lines.

TRACHEOTOMY is the operation of cutting into the trachea. It is sometimes also called Bronchotomy; and a similar operation on the lower part of the larynx is named Laryngotomy. The anatomy of the parts principally concerned in these operations will be found in the articles Larynx and Respiration, in Nat. Hist. Div.

Tracheotomy may be performed for several purposes; as, to form an aperture either for the admission of air into the lungs, when the larynx, fauces, or upper parts of the air-passages are obstructed, or for the extraction of foreign bodies from the adjacent parts of the air-passages, or for the facility of inflating the lungs in suspended animation. In the first view it may be necessary in many diseases; such as croup, acute laryngitis, œdema of the glottis, severe cases of quinsy, tumours, and other growths in the larynx or pressing on it, and diphtheria; in all of which the aperture through the glottis is frequently closed, not merely by the swelling of the membranes around it, or the enlargement of the adjacent parts, but by the spasmodic and fixed contraction of the muscles whose office it is to approximate the vocal ligaments. The relief afforded by the operation is often instantaneous, and, for a time, complete; but its ultimate results are less certain, for though it may be sufficient to prevent the impending suffocation, it has no influence in arresting the original disease. On the contrary, the operation itself is not without danger; and that, both from the accidents that may occur in its performance, and from its subsequent effects; and therefore, although no general rule can be laid down, its performance should not be undertaken unadvisedly, nor in any cases in which it is not absolutely and almost immediately necessary for the preservation of life.

In its performance a vertical incision is first made in the median line of the throat, either below the thyroid gland, or more or less above it, according to the circumstances of the case and the object to be accomplished. The dissection must then be continued carefully onwards in the same direction, pushing aside the sterno-hyoid muscles, and whatever vessels lie in or near the middle line, till the trachea is completely exposed. When the hemorrhage has ceased, or is but slight, the trachea must be opened, first by a vertical incision, and then by removing portions of one or more of its rings, according to the size of the aperture that is required. Through the opening a short silver canula must be introduced, and, as often as is rendered necessary by mucus accumulating in it, must be removed, cleaned, and again introduced. The means to be subsequently adopted must vary with the circumstances of each case: if the obstruction is removed, the wound in the trachea may be healed, but if not, the canula must be worn for the rest of life. If the operation were performed for the removal of a foreign body, or for the inflation of the lungs, no canula need be introduced, but the wound should be closed as soon as the main object is attained.

TRACTION, in Mechanics, is the act of drawing a body along a plane, usually by the power of men, animals, or steam; as when a vessel is towed on the surface of water or a carriage moved upon a road. The power exerted in order to produce the effect is called the force of traction.

Numerous experiments have been made for the purpose of ascertaining the value of a force so exerted; and when men are employed to draw laden boats on canals, it is found that if the work be continued for several days successively, of eight hours each, the force of traction is equivalent to a weight of 31¼ lbs., moved at the rate of two feet per second, or 1⅓ mile per hour (it being understood that such weight is imagined to be raised vertically by means of a rope passing over a pulley, and drawn in a horizontal direction). The force of traction exerted when, without moving from his place, a man pulls horizontally against a weight so suspended, is estimated at 70 lbs. The action of a horse in drawing a vessel on a canal is said to be equivalent to a weight of 180 lbs. raised vertically, as above supposed, with a velocity of 3⅓ feet per second, or 2¼ miles per hour; but this estimate has been considered too high; and from experiments which have been made on the power of horses in waggons, carts, and coaches, on level ground, it is found that the force of traction exerted by a stout horse is equivalent to 80 lbs. raised at the rate of 4⅖ feet per second, or 3 miles per hour. Mr. Tredgold considers that a horse exerts a force of traction expressed by 125 lbs. raised at the rate of 3⅔ feet per second, or 2½ miles per hour. A man or a horse can however double his power of traction for a few minutes without being injured by the exertion; and when the carriage is in motion, so that the friction on the ground is alone to be overcome, a horse can draw, during a short time, on a level road, a weight exceeding 1500 lbs.

The force of traction is found to vary nearly with the term $(w-v)^2$, where w is the greatest walking velocity of a man or horse when unresisted (6 feet per second, or 4 miles per hour, for a man; and 10 feet per second, or 6¾ miles per hour, for a horse), and v is the velocity with which the vessel or carriage is moved. From theoretical considerations it has been determined that the greatest effect is produced when the velocity of the object moved is one-third of that with which the man or animal can walk when unresisted.

If a wheel-carriage were situated on a level plane which opposed no resistance, it is evident that, whatever were the diameter of the wheels, the smallest conceivable power of traction applied to the axle would suffice to put the carriage in motion. But when a wheel in moving meets with an obstacle on the ground, that obstacle is pressed at the point of contact by a force acting in the direction of a line drawn to it from the centre of the wheel, and arising from that part of the weight which is supported by the wheel, together with the force of traction; therefore by the "resolution of forces," the ratio between the resistance which is to be overcome by the moving-power and the weight on the wheel will become less as the diameter of the wheel is increased: also the most advantageous direction in which the force of traction can be exerted is perpendicular to the line of pressure drawn from the centre of the wheel to the obstacle. But the height of the wheels cannot exceed certain limits depending on the use to which the carriage is applied; and when the latter has four wheels, the height of those which are in front must be such only as will allow it to be turned round within a given space; also, when a horse is employed to move a carriage, attention must be paid to the conditions under which his power may be advantageously exerted.

It was first observed by M. Deparcieux, and published in the 'Mémoires de l'Académie des Sciences,' 1760, that horses draw heavy loads rather by their weight than by their muscular force. Dr. (Sir David) Brewster has also remarked that when the resistance is great a horse lifts both its fore-feet from the ground; then, using his hinder-feet as a fulcrum, he allows his body to descend by its weight, and thus overcomes the obstacle: and it may be added that when this action takes place with a two-wheeled carriage, if the loading is disposed so that some portion of it may press on the horse's back, the effect of the animal's weight will thereby be increased. Now if the traces, or the shafts of the carriage, were attached to the horse's collar near his centre of gravity, a line imagined to be drawn from the latter point to his hinder-feet may represent his weight, and a line drawn perpendicularly from his feet upon a plane passing through the traces or shafts may represent the lever of resistance: but while the former line remains the same, this lever becomes less as the plane of traction (that of the traces or shafts) inclines more upwards from the wheel; and therefore, in order that the power of the horse may be advantageously applied, the diameter of the wheel should be as small as is consistent with other circumstances.

Experiments have shown that when the angle of traction, as it is called, that is, the angle which the plane of the traces makes with the road on which the carriage is moving, is 15 or 16 degrees, a horse pulls with good effect: and the height of the points at which the traces are attached to a horse's collar being about 4 feet 6 inches from the ground, it follows that, in order to obtain this inclination, the lower extremities of the traces or shafts should be 2 feet 3 inches from the ground. In general however, in two-wheeled carriages, the height of these extremities is about 3 feet.

As an example of the force of traction exerted by steam, it may be stated that on a level line of railway, an engine with an 11-inch cylinder, and having an effective pressure of 50 lbs. per square inch in the boiler, drew 50 tons at the rate of 30 miles per hour, working 10 hours daily; and that the same engine, with an equal pressure in the boiler, drew 160 tons at the rate of 15¼ miles per hour. (Pambour 'On Locomotive Engines.') The resistances to be overcome, or, in other words, the efforts of traction required upon the various systems of intercommunication, may be stated as follows:—

	Ratio of Traction to weight.
Ordinary macadamised roads in good state, horse walking at useful velocity	1 to 20, or 25
Ordinary macadamised roads in good state, horse trotting	1 to 14
Ordinary macadamised roads, paved, horse walking . .	1 to 50
Wooden road ,, .	1 to 70
Tramway, of granite blocks, horse walking . . .	1 to 180
Railways, velocity 20 miles per hour	1 to 200
,, ,, 30 miles per hour	1 to 100
Canal of small section, small velocity, 2 miles per hour .	1 to 600
,, ,, ,, 4 miles ,, .	1 to 150
,, ,, ,, 8 miles ,, .	1 to 37
Canal of large section, 2 miles per hour	1 to 1000
,, ,, 4 miles per hour	1 to 250
,, ,, 8 miles per hour	1 to 62

TRACTRIX, or **TRACTORY**, the name given to a curve described by a heavy point attached to a string, the other end of which is moved along a given straight line or curve. For some account of this curve, which is of no interest except as a mathematical exercise, see Peacock's Examples, page 174.

TRADE, BOARD OF. The department of the English government popularly known under this title is a committee of the Privy Council, and its proper designation, which correctly defines its principal functions, is—"The Lords of the Committee appointed for the consideration of all matters relating to Trade and Foreign Plantations." This department is practically under the direction of a president and vice-president; the other members of the Board or Committee are,—the Lord Chancellor, the Archbishop of Canterbury, the First Lord of the Treasury, the principal Secretaries of State, the Chancellor of the Exchequer, the Speaker of the House of Commons, the Chancellor of the Duchy of Lancaster, the Paymaster of the Forces, the Treasurer of the Navy, the Master of the Mint, and such officers of state in Ireland as are privy councillors in England; but those functionaries do not ordinarily interfere with or assist at the deliberations of the president and vice-president. The clerks of the council are, *ex officio*, secretaries of the Board of Trade, but that duty is performed by two joint assistant-secretaries.

The president and vice-president of the Board of Trade exercise, in effect, the duties which in other countries are performed by the minister of commerce. Their office is not indeed executive, but rather consultative, the orders rendered necessary by their decisions being given by the Lords of the Treasury or by the secretary of state, as the case may require. The functions of this board have been of late years considerably extended, its duties being some of them of a ministerial, and others of a judicial character. It has the general superintendence of matters relating to merchant ships and seamen, and the carrying into execution of the statutes in force relating to them. For that purpose it has to require and receive various kinds of returns as to trade and navigation, and originate and consider reports made to it by its inspectors and other officers. It has also a partial control over local marine boards, and may lay down rules as to the conduct of examinations, and as to the qualification of applicants for the posts of masters and mates of foreign-going as well as of home-trade passenger-ships. [SHIPS.] It grants licences to persons to engage or supply seamen or apprentices for merchant ships in the United Kingdom, adjudicates on claims for wages, and investigates cases of alleged incompetency and misconduct (17 & 18 Vict. c. 104). The Board also appoints officers to report on the condition of steam-vessels and their machinery (14 & 15 Vict. c. 79).

The Board of Trade exercises a supervision over railways and railway companies, not only with respect to their original formation, but also as to their subsequent working. Railways were first placed under this control by the statute 3 & 4 Vict. c. 97. A few years afterwards the powers of the Board in this respect were transferred to a Board of Commissioners of Railways; but in 1851 all the powers of this latter board were transferred to the Board of Trade (14 & 15 Vict. c. 64). Notices of application for Railway Acts, accompanied by plans, must be deposited with the Board, before any bill can be introduced into Parliament; and before a line can be opened for traffic, notice must be given to the Board, and its permission obtained, on the report of an inspector, appointed by the Board for those and other general purposes. So, when accidents occur, notice must be given to the Board, and an inspector is generally sent to inquire into the circumstances, and on his report the Board may cause alterations to be made for the greater safety of the public.

The Board of Trade, through the medium of its registrar, is also charged with the registration of all Joint-Stock Companies (19 & 20 Vict. c. 47). By the statute giving a copyright in designs, their registration is effected by the Registrar of the Board of Trade (5 & 6 Vict. c. 100; 6 & 7 Vict. c. 65; 13 & 14 Vict. c. 104; 14 & 15 Vict. c. 8; 15 & 16 Vict. c. 6). The Board also controls the proceedings of the Commissioners for regulating the employment of coal-whippers and the discharge of coal-laden vessels in the port of London (6 & 7 Vict. c. ci. (local and personal); 9 & 10 Vict. c. xxxvi.; 14 & 15 Vict. c. lxxviii.). A department of the Board of Trade has the immediate control of the Government schools and museums of science and art, as explained under SCIENCE AND ART, DEPARTMENT OF. Lastly, another department of the Board of Trade is charged with the collection and publication of tables, containing information with respect to the revenue, trade, commerce, wealth, population, and other statistics of the United Kingdom and its dependencies, as well as of foreign countries. The officers of another department collect and prepare the tables of the prices of corn, which formerly, and before the abolition of the corn-laws, regulated the amount of duty, and still govern the rent-charge in lieu of tithe under the Tithe Commutation Act (Blackst. 'Comm.,' Mr. Kerr's edit.).

TRADE AND SHIPPING. The foreign trade of England is coeval with its earliest history. It must not, however, be supposed that the commercial dealings of those early days bore much resemblance to those of more modern times. The visits of foreigners to our shores (for England was an exporting country before its inhabitants were become ship-owners or navigators) were then confined to procuring tin from Cornwall. We may be certain that those by whom this earliest British trade was conducted did not obtain the metal without leaving in exchange that which was considered more valuable by the miners. Of what those importations consisted we are not precisely informed. "Salt, earthenwares, implements made of copper, of ivory, and of amber," are said to have formed the principal merchandise at that time imported into Britain; but no mention is made of wool, which afterwards, and at a comparatively remote period of our annals, became a principal article of export from this country. We learn from Madox's 'History of the Exchequer' that in the reign of Richard I. Gervase de Aldermanbury accounted, as chamberlain of London, for money received as fines from merchants for leave to export wool. In 1275, according to Rymer (tom ii., p. 50), wool was allowed to be exported upon payment to the king of 10s. per sack. Within the next twenty years the custom of wool was raised to 20s. the sack, and in 1296 was further raised at the will of the king to 40s. the sack. This export duty has been justified on the ground of its being a tax upon the foreign manufacturers or consumers, to whom English wool was an article of necessity; but the duty acted as a burden upon the grower, not only in respect of his surplus quantity which was necessarily exported, but also because the price of the remainder was as necessarily governed by the net value that could be obtained for that surplus. Accordingly we find that this imposition of customs upon the export of wool was a frequent cause of ill feeling between the commons and the crown.

In a statement of the trade of England, said to have been found upon record in the Exchequer, and quoted in a tract called the 'Circle of Commerce,' published in 1623 by Edward Misselden, the list of our exports comprised only wool, coarse woollen cloths, and a small quantity of leather, amounting in value to 294,184l., including the export-duty; while the imports included fine woollen cloths, wax, wine, linen cloth, mercery, and grocery wares, to the amount of 38,970l. The shilling at that time contained 213 grains of silver. Taking into account the different value of money then and at present, these values are equivalent to 728,606l. and 96,518l. of the present coin respectively. This statement of imports and exports does not appear entitled in all respects to be considered accurate; but it is remarkable that this circumstance was brought forward and commented upon as the proof of "an extraordinary balance of trade in favour of the nation," a strange conclusion from such premises. It is now generally acknowledged that the commerce of a country to be successful must include in the value of its imports the whole value of its exports, together with the gain which forms the sole inducement of the merchants by whom it is prosecuted.

Still, however, the trade and commerce increased, and from the beginning of the present century has continued to increase till it has attained a most colossal importance. This has arisen in a great degree from a juster perception of the true principles of political economy, and also from the vast improvement in mechanical contrivances for the diminution of mere manual labour, of which the application of the powers of steam by the invention of Watt, may be deemed the chief. It is due also to the memory of Pitt to say, that he early perceived the truth of the principles propounded by Adam Smith, and in the commencement of his career endeavoured, though circumstances rendered his efforts ineffective, to establish a more liberal, if not an entirely free trade. Old prejudices and the war with France combined to prevent the adoption of those principles, and the first quarter of the century showed little permanent increase. Thus the official value of imports in 1802 amounted to 29,826,210l., and the declared value of exports to 45,102,330l.; while, with considerable fluctuations in the interval, in 1825 the imports only reached 44,137,482l., and the exports 38,877,388l., the latter year including Ireland, which the former does not, but the amount of Irish trade was not great. The official valuation is, however, deceptive, as the price fixed does not represent the real value. This commerce was carried in 1802 inwards by 7806 British ships, registered at 1,333,005 tons, and 3728 foreign ships with a total of 480,251 tons, and outwards in 1802 by 7471 British ships, registered at 1,177,224 tons, and 3332 foreign vessels with 457,580 tons. In 1836, the official value of imports had increased to 57,023,867l., and the declared value of exports to 53,368,571l., and the number of British ships inwards to 14,347, of an aggregate burden of 2,505,473 tons, and outwards to 14,207, of a burden of 2,531,577 tons, and the foreign ships inwards to 7131, of a burden of 988,899 tons, and outwards to 7048 ships, and a burden of 1,035,120 tons. In 1846, the tariff was materially reformed, and successive improvements have been since introduced; and in 1854, the real value of the total imports into the United Kingdom was 152,389,053l.; in 1855 it was 143,542,850l., and in 1856 it was 172,544,154l. These values are computed from the average prices fixed for the articles, which are chiefly entered by quantities at the Custom House. The value of the exports is obtained from the declared value set on the articles, except in the case of foreign and colonial produce, of which the price is computed in the same way as with the imports. In 1854 the total value of exports amounted to 115,821,092l., of which 97,184,726l. were for the produce or manufacture of the United Kingdom, the remainder being for foreign or colonial produce. In 1855 the total value was 116,691,300l., of which 95,688,085l. were for the produce or manufactures of the United Kingdom; and in 1856 the total value amounted to 139,220,353l., of which 115,826,948l. were for home productions; the official values of the exports show a singular contrast to the real values; they are for the three years respectively, 29,808,044l., 31,494,391l., and 33,423,724l. The official values of the imports for the three years show less discrepancy; they were 124,136,018l., 117,284,881l., and 131,937,763l.

The remissions or reductions of duties on imports during the succeeding years contributed to the continued increase of trade and commerce; for the year ending December 31, 1860, the amount of the principal articles imported was 169,131,063l., and this does not include a variety of other importations, of which many are of large amount, as, for instance, animals, living, of which in the year there were imported 77,010 oxen, bulls, and cows, 27,559 calves, 320,219 sheep, and 24,452 swine and hogs; pearl and potashes, of which there were imported 141,087 cwts.; bark, 418,069 cwts.; brimstone, 1,007,503 cwts.; bristles, 2,534,217 lbs.; caoutchouc, 43,039 cwts.; clocks and watches, 497,386 in number; nor eggs, in number 167,695,200, with a few other items.

The principal articles imported, in addition to those above mentioned, were—in articles used for diet—coffee to the value of 2,543,211l., of which 1,813,213l. was from Ceylon; 387,226l. from other British possessions, and the remainder from foreign countries. Corn to the value of 16,554,083l., of which 4,323,808l. was from the United States; 3,551,907l. from Russia; 3,410,161l. from Prussia; 1,610,762l. from France; and the rest from Egypt, Moldavia, Wallachia, and other countries. Barley, oats, peas, beans, and Indian corn to the value of 10,558,162l. Wheat-meal and flour to the value of 4,320,558l., of which the United States supplied to the value of 1,826,582l.; France, 1,594,030l.; and the rest from the Hanse towns and other countries. Currants and raisins to the value of 1,253,670l. Bacon, 870,286l. Butter, 4,078,017l. Cheese, 1,597,569l. Eggs, 478,658l. Rice, not in the husk, 1,023,108l. Spirits—rum, brandy, and Geneva, to the value of 1,918,839l.; and wine to that of 4,201,434l., of which 1,734,613l. was contributed by Spain; 1,036,620l. by France (almost twice as much as in 1859); 898,336l. by Portugal, and the rest by various countries. Sugar of all kinds, including sugar-candy and molasses, to the value of 12,106,069l., of which, of the raw sugar of all kinds 7,110,203l. came from British possessions, and 4,727,658l. from foreign countries. Tea, 6,944,042l., an increase of 1,132,497l. over 1859. Tobacco, to an aggregate of 1,777,632l. Of articles used in manufactures, we imported cotton to the value 'of 35,756,889l., the United States supplying it to the amount of 30,069,319l.; the British East Indies, 3,373,614l.; Egypt, 1,480,895l.; Brazil, 561,949l.; and only 271,112l. from all other countries. The total quantity imported was 1,390,938,752 lbs. Flax to the value of 3,836,770l. was imported, three-fourths being from Russia and Prussia; and hemp valued at 1,199,018l., of which 907,442l. was from Russia, the rest from various countries, with jute and other substances used as substitutes for hemp to the value of 665,764l. Hides, dry, wet, and tanned, or dressed, to the value of 3,296,512l. Indigo, to the value of 2,528,888l. Of metals—copper to the amount of 2,213,141l., Chili and Cuba furnishing the largest amount, though Australia sent ore to the amount of 173,061l.; iron, 659,620l.; lead, 468,435l.; spelter, 499,636l.; tin, 387,307l. Oils—train, spermaceti, palm, and olive—to the value of 3,923,235l. Saltpetre and cubic nitre to the value of 1,165,815l. Silk, raw and thrown, to the value of 10,323,837l., of which raw silk to the value of 6,829,496l. were supplied by the British East Indies and Egypt, 2,185,742l. by China, while the whole of the thrown silk only amounted to 336,991l., of which 172,357l. came from France. Tallow, to the value of 4,014,280l., of which 3,040,997l. was supplied by Russia, only 33,830l. by Australia, and the rest by South America and other countries. Timber, to the aggregate value of 9,206,092l., of which British North America contributed 4,309,235*l.*; Sweden and Norway, 2,169,545*l.*; Prussia, 1,093,412*l.*; Russia, 783,388*l.*; and the remainder by various countries. Wool, to the value of 10,704,922*l.*, of which 5,387,078*l.* was furnished by Australia; 1,187,748*l.*, by British possessions in South Africa; 699,861*l.*, by the British East Indies; and the rest from various places, chiefly through the Hanse towns; together with alpaca and llama wool to the value of 326,557*l.*, and woollen manufactures not made up, to that of 918,927*l.* For agricultural purposes, we imported guano to the value of 1,563,145*l.*; oil-seed cakes to that of 910,840*l.*, and flaxseed and linseed to the amount of 3,391,938*l.*; but of this a large portion was for manufacture into oil. The total imports amounted to 210,648,643*l.* The customs duties for the year amounted to 23,032,395*l.*, a decrease of 1,862,184*l.* on those of the preceding year.

The declared value of British and Irish produce and manufactures exported during the same year (1860) was 135,842,817*l.* This does not include the foreign and colonial articles re-exported, which amounted in declared value to 5,136,652*l.* The chief articles were—apparel and slops, to South Africa, Australia, other British possessions, and to foreign countries, 2,156,348*l.* Beer and ale, of which the East Indies, Australia, and the United States were the chief consumers, 1,863,998*l.* Printed books, 494,915*l.* Butter, 633,280*l.* Cheese, 118,859*l.* Coals and culm, 3,321,539*l.*, of which France took 566,109*l.* Cotton (woven), 40,342,819*l.*, of which the Hanse towns took 1,191,703*l.*; Turkey, 2,789,954*l.*; Egypt, 1,045,988*l.*; the United States, 3,848,750*l.*; foreign West Indies, 1,062,965*l.*; Brazil, 2,300,101*l.*; China, 3,157,359*l.*; Java, 1,057,617*l.*; British North America, the West Indies, and South Africa, 1,528,106*l.*; the East Indies, 10,518,094*l.*, no other country reaching to a million; while other cotton manufactures, such as lace, net, stockings, counterpanes, and small wares, and sewing thread, were exported to the value of 1,795,593*l.*, and cotton yarn to the amount of 9,875,073*l.* Earthenware and porcelain, 1,440,998*l.* Glass—flint, window, bottles, and plate, 653,224*l.* Haberdashery and millinery, 4,011,277*l.* Hardware and cutlery, 3,772,035*l.* Leather, tanned and manufactured, 2,129,094*l.* Linens (woven), 4,432,823*l.*, with thread lace, thread and tapes, 369,380*l.*, and linen yarn, 1,800,927*l.* Machinery, including steam-engines, 3,825,361*l.* Metals:—iron, including pig, bar, railway, wire, cast, wrought of all kinds, and steel, 12,158,355*l.*; copper, of all sorts, including brass, 3,001,992*l.*; lead, of all sorts, 699,648*l.*; tin and tin plates, 1,862,150*l.*, of which the United States took 1,018,056*l.* Oils, from seeds, 1,132,324*l.* Silk, manufactured, 1,577,001*l.*; with thrown silk and silk twist and yarn, 822,291*l.* Soap, 249,876*l.* Soda, 982,906*l.* Spirits, British, 286,651*l.* Stationery, 720,721*l.* Sugar, refined, 239,762*l.* Telegraphic wire and apparatus, 250,655*l.* Wool, 868,781*l.* Woollen cloths and other manufactures, 12,192,861*l.*, for which the United States were the largest customers, though the dispersion is pretty general; and woollen and worsted yarn, 3,843,396*l.*

Shipping.—This enormous trade requires a corresponding amount of shipping. In 1860, there were entered inwards with cargoes 20,104 British ships, of an aggregate burden of 5,762,464 tons, an average of 286 tons each; and 18,270 foreign vessels of 4,292,823 tons, an average of 235 tons; an increase of both British and foreign over the years 1858 and 1859: and there were cleared outward with cargoes 23,713 British ships, of an aggregate burden of 6,359,103 tons, an average of 260 tons each; and 20,777 foreign ships of 4,425,433 tons, an average of only 205 tons. The greatest number of foreign ships was that of the Danes, 2957 entered inward, and 3362 cleared outwards; the Norwegians sent 2862 vessels, and cleared out 1746; but the shallow waters of the Baltic necessitate the use of small ships, so that the tonnage of the two inwards was only 929,483, outwards 677,605 tons, an average of only 140 tons each. The largest amount of tonnage is by the United States, who entered 1,361,021 tons in 1417 ships; and cleared out 1,367,988 tons, in 1456 ships, an average of 945 tons each. Inwards Russia sent 435 ships of 125,612 tons; Sweden, 1119 ships of 181,755 tons; Prussia, 1795 ships of 425,436 tons; Mecklenburg and Oldenburg, 722 ships of 144,088 tons; Hanover, 970 ships of 81,196 tons, an average of only 84 tons; the Hanse Towns, 580 ships of 212,006 tons; Holland, 1501 ships of 185,098 tons; Belgium, 257 ships of 54,166 tons; France, 2187 ships of 186,524 tons; Spain, 244 ships of 67,048 tons; Portugal, 147 ships of 33,638 tons; Sardinia and Sicily, 493 ships of 118,914 tons; Austria, 467 ships of 152,058 tons; Greece, 59 ships of 16,125 tons; other European countries, 38 ships of 12,280 tons; and other countries in America, Asia, and Africa, 20 ships of 6355 tons. Outwards there were cleared, in addition to those mentioned above, from Russia, 396 ships of 116,991 tons; Sweden, 1163 ships of 185,192 tons; Prussia, 1595 ships of 350,088 tons; Mecklenburg and Oldenburg, 905 ships of 100,222 tons; Hanover, 1666 ships of 134,919 tons; Hanse Towns, 867 ships of 290,788 tons; Holland, 1756 ships of 260,050 tons; Belgium, 262 ships of 59,102 tons; France, 4068 ships of 430,440 tons, a remarkable difference from those entered inwards; Spain, 221 ships of 61,383 tons; Portugal, 143 ships of 31,021 tons; Sardinia and Sicily, 553 ships of 139,301 tons; Austria, 501 ships of 163,091 tons; Greece, 44 ships of 15,684 tons; other European countries, 44 ships of 15,684 tons; and other countries in America, Asia, and Africa, 19 ships of 6081 tons.

The coasting-trade, including that between Great Britain and Ireland, is even larger in amount of tonnage; but as the return gives the repeated voyages when entered or cleared with cargoes, the number of ships employed is not shown, but only the number of voyages made. These, in 1860, were, inwards, 153,782, and the aggregate burden was 17,003,411 tons, of which only 102,223 tons came in 666 foreign bottoms. Outwards there were cleared 157,419 ships of 17,014,399 tons, of which 644 foreign vessels carried 100,056 tons.

The total number of registered ships in 1860, not including river steamers, was 20,019, of an aggregate burden of 4,251,739 tons; of these 929 were steamers of 399,494 tons burden. The number of men employed in these vessels was 171,592, exclusive of masters. The total number of vessels built and registered in the year was 1016 of 211,968 tons burden, of which 198 were steamers of 53,796 tons burden.

TRADE WINDS. [WINDS.]

TRADER. [BANKRUPT.]

TRADITION (from the Latin *tradere*) comprises, in the widest sense of the word, all that has been handed down (quæ tradita sunt) to us concerning the events of the past, and in this sense all history is tradition. In the early ages of mankind and of every nation, when the art of writing was unknown or little used, all history was handed down by oral communication from generation to generation without written records. Afterwards, when the accounts thus propagated were written down and assumed a definite shape, or many shapes, according to the information, the opinions, or the judgment possessed by the person or persons who wrote them down, such accounts were found to differ materially from accounts written by eye-witnesses at or soon after the times when events happened. Historical criticism distinguishes the two kinds of history by calling the former *tradition*, in a narrower sense of the word, and the latter *history*. Those who know how, even in our days, reports are changed and embellished, how some features are omitted and others added during the process of passing from mouth to mouth, and how in the end they frequently assume a totally different aspect from what they originally had, will readily admit that such traditions cannot be received with the same faith as contemporary history. We may add that the more important the occurrence handed down by tradition is, and the more it affects the feelings and passions of men, the greater will be the changes and corruptions which it experiences in its progress. The desire, moreover, of seeing things clear and complete is inherent in the human mind; and hence we find that in innumerable instances where a tradition or a series of traditions was deficient, unclear, or incomplete, man's imagination and ingenuity have been at work, to make up an apparently complete account, either by filling up the gaps in the original account with pure fictions, or by transferring and combining events which belong to different times and countries. Such accounts require to be examined with more caution on the part of the historian the more skilfully they are made up, and the more their apparent consistency resembles real history. It is the business of the historian who feels the want of a positive conviction, and is not satisfied with discovering that a tradition is obscure, inconsistent, or incredible, to find out its historical groundwork, by comparing the traditions about one and the same subject, by analogies, and by separating such additions and embellishments which have been made with a view to satisfy man's curiosity, or his feelings, either religious or political. The historian who undertakes this task has to guard against two dangerous rocks: the one is the desire to construct out of a tradition a history according to a preconceived notion or theory, the very thing which in many cases was the cause of the adulterated tradition itself; and the other is the so-called rationalistic mode of dealing with tradition, which consists in stripping it of everything poetical or marvellous, and leaving nothing but a skeleton, which is considered as history merely because it presents nothing that might not happen every day and within our own experience.

In the history of Christianity the term tradition has been applied to the so-called unwritten word of God; that is, to the doctrines said to have been communicated by Christ to his apostles, which were not written down by them, but were handed down by their oral instruction to their successors. This tradition is preserved in the writings of the ecclesiastical fathers; and the Church of Rome regards them, next to the Bible, as a source of knowledge which ought to regulate the life and religious observances of Christians. She claims for tradition the same unconditional faith in regard to its divine authority as for the doctrines of the New Testament. The substance of the tradition thus revered by the Church of Rome, however, affects rather the forms of religion than its essence; and some of these forms, such as the baptism of infants, the celebration of certain festivals, and the like, are retained and observed by the majority of Protestants, while on the whole they reject tradition, and do not consider it binding.

TRAGACANTH, familiarly termed *Gum-dragon*, is the produce of several species of the genus *Astragalus*. [ASTRAGALUS, in NAT. HIST. DIV.] The *A. verus* (Olivier,) a native of the north of Persia, Armenia, and Asia Minor, yields the greater part of what is used in Europe. Persia supplies it likewise to India, Baghdad, and Basrah. *A. gummifer* (Labill.) yields some of the white tragacanth. *A. creticus*, Lamarck (*Tragacantha Cretica incana*, Tournefort), yields it sparingly; while, according to Sibthorp ('Prod. Fl. Græcæ,' ii. 90), the tragacanth which is used in Italy is obtained in Greece from the *A aristatus* (Villars), and which, according to Sibthorp, yields the tragacanth of Dioscorides. The *A. tragacantha* (var. *a.* Linn.), the *A. Massiliensis* (Lamarck et Dec.), long reputed to be the source of tragacanth, yields no concrete gum, but merely a gummy juice, which is used in confectionary. The *A. Dicksonii* (a name substituted by Dr. Royle for *A. strobiliferus* of Lindley) yields the reddish-coloured tragacanth. In the hot months of July and August, particularly after a dewy or a cloudy night, the branches of *A. verus* are found encrusted with tragacanth. It is not procured by artificial incisions, but exudes spontaneously from natural clefts in the bark, or from punctures made by insects, or more probably by a subepidermal fungus, like the *nemaspora crocea*, as the shrubs from which the juice exudes are always in an unhealthy state, or ready to perish. (Decandolle, 'Phys. Veg.,' i. p. 174.)

In commerce tragacanth occurs in two forms, termed vermiform, and flake or cake tragacanth. The former, called also *Morea tragacanth*, is not frequent in this country. It is mostly in small twisted thread-like pieces, seldom in flat or bandlike portions, of a variable size, of a whitish colour. The larger irregular pieces often run together, and are of a yellow or yellowish-brown colour. White worm-like pieces are selected and sold as vermicelli. Flake or Smyrna tragacanth occurs in tolerably large, broad, thin pieces, with concentric elevations or lines, seldom of a filiform shape: colour whitish. Both sorts are hard, yet somewhat soft and even flexible before breaking; fracture dull and splintery. It is with difficulty reduced to powder, except in winter, or in a heated mortar. It is devoid of taste and smell. It swells in the mouth, and is lubricous. Fine tragacanth is not rendered blue by iodine, but the *Morea tragacanth* is affected by it, as well as an artificial substance prepared by boiling starch, which last article, called tragacantin, does not swell in water. Kutera gum, the produce of a species of cochlospermum and sterculia, which is sometimes mixed with or substituted for genuine tragacanth, is not affected by tincture of iodine. It always occurs in stalactite-like pieces, and consisting almost entirely of bassorin, is scarcely soluble in water. [GUM.]

Tragacanth approximates more to starch than common gum, than which it is more nourishing, but less digestible. Tragacanth is to be preferred to gum-arabic to form a mucilage, as one part will inspissate fifty parts of water. It is better to allow pieces of tragacanth slowly to dissolve in cold water than to use the powder with boiling water. Both the mucilage and powder are used to suspend heavy powders in water; also to make lozenges and pills. For electuaries it is improper, as it renders them slimy on keeping. As a demulcent, or means of sheathing the fauces and intestines, it is preferable to gum-arabic, its insolubility rendering it a more efficient protection to the mucous membrane against either acrid poisons or unhealthy secretions. Thus in India, tragacanth boiled in rice-water is advantageously administered in dysentery and bloody fluxes. Externally, a thick mucilage of tragacanth is a good application to burns, to exclude the air.

TRAJECTORY, the technical name which was formerly given to a curve, that is, to a curve required to be found by means of given conditions; most frequently used for the required path of a particle acted on by given forces. The term is now seldom used.

TRAMMELS, the name of the ELLIPTIC COMPASSES, described in that article, in which a bar carrying a pencil is guided by two pins which move in grooves.

TRAMWAY. A track laid down on the surface of a common road, for the purpose of diminishing the effort of traction required in moving wheeled vehicles; and for this purpose it is necessary that the material of the tramway should be practically incompressible, and as smooth as possible. Iron, wood, marble, and granite are used in the formation of tramways, as in the cases of Train's Street Railways, the forest roads in wood countries, in the Italian cities, and in the Commercial Road, London Docks. See RAILWAYS; TRACTION.

TRANSCENDENTAL, a mathematical term of description, the meaning of which is not very uniform. When any particular formula is incapable of being expressed by any particular range of algebraical symbols, it is, with respect to those symbols, transcendental—that is, it transcends or climbs beyond the power of those symbols. The word was perhaps first used by Leibnitz ('Leipzig Acts,' 1686), who says, "placet hoc loco, ut magis profutura dicamus, *fontem aperire transcendentium quantitatum*, cur nimirum quædam problemata neque sint plana, neque solida, neque sursolida, aut ullius certi gradus, sed omnem æquationem algebraicam transcendant." Here, then, is the first meaning of the word; a transcendental problem is one the equation of which is infinitely high, or contains an infinite series of powers of an unknown quantity, so that its highest degree transcends every degree.

To form an idea of what is now most commonly meant by transcendental, it will be desirable to recapitulate the steps by which algebra has arrived at its present state of expression,—or, rather, mathematical analysis, as those would say who do not like to call the differential calculus by the name of algebra.

And first we have the state which preceded the time of Vieta, in which formulæ were mostly described in words, and the adoption of arbitrary symbols of quantity was only of casual occurrence.

Next, we have the introduction of arbitrary symbols of quantity by Vieta, but not to the extent of using arbitrary numbers of multiplications, or algebraical exponents. Here what we now call a^n was transcendental; Vieta could have described a^6 by *a* cubo-cubum, or a^7 by *a* quadrato-quadrato-cubum, but a^n had neither name nor symbol.

Thirdly, we have the stage which began with Harriot and Descartes, and which brought ordinary algebra into substantially its present form. During these periods, however, geometry and arithmetic, without help from algebra, had brought into use sines, cosines, &c., and logarithms, which were then properly transcendental. The words which described a particular mode of drawing lines in a circle, or the result of many interpositions of geometrical means between two given numbers, did not place those lines or means among the objects of algebra, and gave no clue to any algebraical properties.

Fourthly, we have the short but interesting period in which, before the formal invention of fluxions or the differential calculus, infinite series began to be employed, and the transcendentals last alluded to ceased to be absolutely incapable of expression. This was the state in which Leibnitz found the science when he first proposed to distinguish between algebraical and transcendental problems.

Fifthly, we have the period succeeding the invention of the differential calculus, in which the areas and lengths, &c., of curves could be expressed, whether they could be reduced into older language or not, by the new signs for fluents or integrals.

Sixthly, we have an alteration which it might have been supposed should have come long before, namely, the expression of the old transcendentals as recognised functions, and the writing of them accordingly, as $\log x$, $\sin x$, $\cos x$, &c. Strange as it may appear, this was never done till the time of Euler. And it is only in our own day that the system has been completed by the recognition of the number whose logarithm is x, the angle whose sine is x, &c., as functions of x, and the adoption of the appropriate symbols $\log^{-1} x$, $\sin^{-1} x$, &c.

Seventhly, a most important addition has been coming into use in the present century,—namely, the employment of definite integrals as modes of expression, not merely of functions of the variable of integration, but of other quantities which only enter as constants, or which, if they vary, vary independently of the variable used in integration. So powerful is this mode of expression, that it may almost be suspected to be final; and the word transcendental is rapidly acquiring a new meaning. We predict that it will settle into the following: a transcendental result will be one which is incapable of expression except by a definite integral, or by an infinite series which cannot be otherwise expressed than by a definite integral.

In the meanwhile there are two senses in which the word is used. The first is that just explained; the second has reference to the old distinction of algebraical and transcendental. A function of x is algebraical when it is finite in form, and x is never seen, nor any function of it, in an exponent, nor under the symbols of a sine, cosine, &c., or a logarithm. No operation then enters with x unless it be one of the four great operations of arithmetic, or else involution or evolution with a definite exponent. Thus, in this sense of the word, $\log x$ and $\sin x$ are both transcendentals. But in the modern sense in which transcendental is not opposed to algebraical, but to that which is expressible by ordinary means, $\log x$ and $\sin x$ are not transcendental, being among the most common of the present modes of expression, and being, in fact, connected with algebra in a way which, had it been understood when these symbols were first used, would probably have always saved them from the distinctive term.

The roots of equations of the fifth and higher degrees are, properly speaking, transcendental: there is no mode of expression except by infinite series. And, generally speaking, and with the exception of a few cases in which modes of expression have been invented and studied, INVERSE functions are transcendental. And a result of such inversions, even though, from our ignorance of its real properties, it may be expressible by ordinary means, is transcendental so long as that ignorance lasts. And it is useful to observe that forms of the most different kind may be connected together by such a relation as this, that both are cases contained under the same transcendental.

To exhibit the arrival of one of these transcendentals of inversion, as they might be called, let us take the equation $\phi x \,.\, \phi' x = \phi(\phi x)$, where $\phi' x$ means the differential coefficient of ϕx. A large class of solutions may be obtained as follows:—The equation $y \log y = \mathrm{C}$ has an infinite number of roots, two at most being real, and all the rest of the form $\alpha + \beta\sqrt{-1}$. Let a, b, c, &c., be any of these roots, and let ψx be a function of x formed as follows:—

$$\psi x = \mathrm{A}a^x + \mathrm{B}b^x + \ldots .$$

where one, two, or any number of roots may be taken at pleasure: and A, B, &c. are any quantities independent of x. Let $\psi^{-1} x$ be the inverse function of ψx, so that $\psi(\psi^{-1} x)$ is x; then $\psi(\psi^{-1} x - 1)$ is a solution of the original equation, or $\phi x = \psi(\psi^{-1} x - 1)$ gives $\phi x \,.\, \phi' x = \phi(\phi x)$. Now $\psi^{-1} x$ is, when more than one root is used, inexpressible except by infinite series: that is, not merely inexpressible in common algebraical terms, but even with the assistance of logarithms and trigonometrical functions. Nevertheless, as particular cases of this solution, both ax and $\sqrt{(b^2 - x^2)}$ are found.

As science advances, quantities which are now called transcendental will lose the name, and be received among the ordinary modes of expression of analysis. One of the first of these will be the well-known function of n, which is generally designated by Γn, and is sometimes called the *gamma*-function, sometimes the factorial function. Its expression is $\int \epsilon^{-x} x^{n-1} dx$ taken from $x = 0$ to $x = \infty$; and when n is an integer it is simply $2 \times 1 \times 3 \times \ldots . \times n$. But when n is a fraction it can only be calculated by series. Nevertheless, as tables are now formed of its values, and as many properties and consequences of it are known, it stands in as favourable a position for use as ordinary logarithms at the end of the 17th century.

TRANSCENDENTAL, a technical term in philosophy, derived from the Latin *transcendere*, to go beyond a certain boundary. In philosophy transcendental signifies anything which lies beyond the bounds of our experience, or which does not come within the reach of our senses. It is thus opposed to empirical, which may be applied to all things which lie within our experience. All philosophy, therefore, which carries its investigations beyond the sphere of things that fall under our senses is transcendental, and the term is thus synonymous with metaphysical. Transcendental philosophy may begin with experience, and thence proceed beyond it; or it may start from ideas *à priori* which are in our mind: in the latter case philosophy is purely transcendental; while in the former it is of a mixed character. [METAPHYSICS.]

TRANSFORMATION, a general term of mathematics, indicating a change made in the object of a problem or the shape of a formula, in such manner that the orginal problem or formula is more easily solved, calculated, or used after the transformation. Thus it frequently happens that the solution of an equation is facilitated by reducing it to another equation having roots which bear a simple relation to the roots of the former: as an instance, we may refer to the solution of the cubic equation in the article IRREDUCIBLE CASE.

All the process of algebra consists in transformation, from and after the point at which the problem to be solved is reduced to an equation: so that to write on this subject in detail would require an article on algebra. A few remarks on the leading points which present themselves in transformations are all we can here undertake to give.

It frequently happens that transformation points out the nature of a consequence in a manner by which the direct reasoning of algebra is strongly confirmed and illustrated. For instance, when we assert that a quantity has two square roots, one positive and one negative, our assertion is easily verified in its positive part: but it does not follow by the same reasoning that a quantity has *only* two square roots. We may say that $x^2=4$ is satisfied by $x=2$, or $x=-2$, because $2\times 2=4$, and $-2\times -2=4$; but how are we to say that there are no other values which satisfy this equation? When we transform the equation $x^2=4$ into $(x-2)(x+2)=0$, with which it is identical, we then see that this product can only vanish when $x-2$ or $x+2$ vanishes; that is, when x is $+2$ or -2.

Transformations frequently leave a point unsettled which can only be determined by a subsequent species of experimental test; or, lest the word experimental as applied to mathematical reasoning should give alarm, by a process of detection which is to choose between alternatives which the process of transformation leaves undecided. This frequently happens when the nature of the transformation is ascertained by means not of the expression to be transformed, but of one of its particular properties. For instance, when we expand a^x into a series of powers of x, supposing we proceed upon the property $a^x \times a^y = a^{x+y}$, we find that there is no series fit to fulfil this condition except

$$1 + \text{A}x + \frac{\text{A}^2x^2}{2} + \frac{\text{A}^3x^3}{2\,.\,3} + \ldots.$$

but we also find that this series is equally fit to fulfil the condition, whatever may be the value of A. So far then our transformation is effected: we see that one among the series formed by giving values to A must be the series we want, if there be any such series. If we make $x=1$, we then immediately detect the condition which is to give the value of A, namely, that A must be so taken as to make

$$a = 1 + \text{A} + \frac{\text{A}^2}{2} + \frac{\text{A}^3}{2\,.\,3} + \ldots.$$

This brings us to the mention of a defect of reasoning which has frequently vitiated mathematical works, namely, the assumption of the species of a transformation, and the supposition that only the character of the details remains to be settled, or the individual of the species to be picked out. In the preceding case, for example, it is often stated as follows: "Required the expansion of a^x in a series of powers of x." The form of the series is then assumed, say $p+qx+rx^2+\ldots.$, and by the use of the property above alluded to, it is found that the series must be of the form $1+\text{A}x+\frac{1}{2}\text{A}^2x^2+\ldots.$ But all that is here proved is, that if a^x be capable of expansion in integer powers of x, the expansion must be of the form $1+\text{A}x+\ldots.$ It is true that, looking at what we see in algebra, that science might be strongly suspected to have a peculiar power of rejecting false suppositions, or of indicating their falsehood by refusing to furnish rational results: thus it certainly does generally happen that when we attempt to select from among series of integer powers the one belonging to an expression which really has no such series, we find infinite coefficients, or some other warning. But it is too much to ask of a beginner that he should take it for granted that algebra has so peculiar a property; nor, in fact, is it true that such a property is quite universal. It is necessary, therefore, to watch all transformations narrowly, both in their general as well as their specific form: first, because there can be no sound reasoning without such caution; next, because, though it be true that in many parts of algebra the science will refuse to acknowledge and obey a false assumption of form, yet it is almost impossible to draw the line at which this refusal ends, and the idea that such a power is universal in algebra will lead the student into many a serious difficulty in the higher branches of mathematics.

TRANSFORMATION OF CO-ORDINATES. We intend this article purely for reference; that is, supposing the subject already known, we mean only to put together the formulæ in such a manner that any one can be used at once.

Rectilinear co-ordinates are the only ones which are usually transformed; such a thing rarely, if ever, happens with polar co-ordinates, except in investigations each of which has its peculiar method. And, first, we shall consider rectilinear co-ordinates in one plane, and afterwards in space. What is usually wanted is to express the co-ordinates of a first system in terms of those of a second, and subsequently given, system.

And, first, as to co-ordinates in one given plane.

1. *Both systems oblique.* Let x and y be the old co-ordinates of a point, x' and y' the new ones. Let μ and ν be the old co-ordinates of the new origin; θ the angle made by the old co-ordinates; ϕ the angle made by the axis of x' with x; ψ the angle made by y' with x. Angles are to be measured as explained in the article SIGN; thus the angle made by x' with x means the amount of revolution which would bring the positive part of x into the direction of the positive part of x', the revolution being made in the positive direction.

$$x-\mu = \frac{\sin(\theta-\phi)}{\sin\theta}\,x' + \frac{\sin(\theta-\psi)}{\sin\theta}\,y'$$

$$y-\nu = \frac{\sin\phi}{\sin\theta}\,x' + \frac{\sin\psi}{\sin\theta}\,y'.$$

2. *The old system oblique, the new one rectangular.* Here $\psi-\phi$ is a right angle, and

$$x-\mu = \frac{\sin(\theta-\phi)}{\sin\theta}\,x' - \frac{\cos(\theta-\phi)}{\sin\theta}\,y'$$

$$y-\nu = \frac{\sin\phi}{\sin\theta}\,x' + \frac{\cos\phi}{\sin\theta}\,y'.$$

3. *The old system rectangular, the new one oblique.* Here, in (1), θ must be a right angle.

$$x-\mu = \cos\phi\,.\,x' + \cos\psi\,.\,y'$$

$$y-\nu = \sin\phi\,.\,x' + \sin\psi\,.\,y'.$$

4. *Both systems rectangular.* Here θ and $\psi-\phi$ are both right angles.

$$x-\mu = \cos\phi\,.\,x' - \sin\phi\,.\,y'$$

$$y-\nu = \sin\phi\,.\,x' + \cos\phi\,.\,y'$$

5. *The co-ordinates of the new system parallel to those of the old one.* Here

$$x-\mu = x',\quad y-\nu = y'.$$

In any of the preceding cases, if the new and old origin coincide, we have only to make $\mu=0$, $\nu=0$, and use the formulæ accordingly.

Next, when the co-ordinates are those of points of space. The only two cases which are particularly useful are when both systems are rectangular, and when the new one only is oblique. Let x, y, z be the old co-ordinates, and x_1, y_1, z_1 the new ones. Let λ, μ, ν be the old co-ordinates of the new origin, and let the angle made by x_1 and y_1 be ζ, that of y_1 and z_1 be ξ, and that of z_1 and x_1 be η, which we may thus denote:—

$$\widehat{x_1y_1} = \zeta,\quad \widehat{y_1z_1} = \xi,\quad \widehat{z_1x_1} = \eta.$$

Then we have the following formulæ:—

$$x-\lambda = \alpha x_1 + \beta y_1 + \gamma z_1.$$

$$y-\mu = \alpha' x_1 + \beta' y_1 + \gamma' z_1$$

$$z-\nu = \alpha'' x_1 + \beta'' y_1 + \gamma'' z_1;$$

Where the meanings of α, β, &c., and the connection of those meanings with the places of the letters in the formulæ, will be easily caught from the following:—

$$\alpha = \cos\widehat{x\,x_1},\quad \beta = \cos\widehat{x\,y_1},\quad \gamma = \cos\widehat{x\,z_1}$$

$$\alpha' = \cos\widehat{y\,x_1},\quad \beta' = \cos\widehat{y\,y_1}\quad \gamma' = \cos\widehat{y\,z_1}$$

$$\alpha'' = \cos\widehat{z\,x_1},\quad \beta'' = \cos\widehat{z\,y_1}\quad \gamma'' = \cos\widehat{z\,z_1}.$$

And α, α', &c., are subject to the following six conditions:—

$$\alpha^2 + \alpha'^2 + \alpha''^2 = 1 \qquad \beta\gamma + \beta'\gamma' + \beta''\gamma'' = \cos\xi$$

$$\beta^2 + \beta'^2 + \beta''^2 = 1 \qquad \gamma\alpha + \gamma'\alpha' + \gamma'\alpha'' = \cos\eta$$

$$\gamma^2 + \gamma'^2 + \gamma''^2 = 1 \qquad \alpha\beta + \alpha'\beta' + \alpha''\beta'' = \cos\zeta$$

This case is not much required. The following, in which both systems are rectangular, is of the highest importance. When we speak of the angle made by two axes, we mean, as before, the angle made by the positive side of one with that of the other; but, since only cosines are used, the direction of revolution is immaterial. If both systems be rectangular, and if they have the same origin, we have two sets of equations, each of which follows from the other, one set being in each column; the meanings of α, α', &c. being as before,

$$\begin{array}{l|l}
x = \alpha x_1 + \beta y_1 + \gamma z_1 & x_1 = \alpha x + \alpha' y + \alpha'' z \\
y = \alpha' x_1 + \beta' y_1 + \gamma' z_1 & y_1 = \beta x + \beta' y + \beta'' z \\
z = \alpha'' x_1 + \beta'' y_1 + \gamma'' z_1 & z_1 = \gamma x + \gamma' y + \gamma'' z \\
\alpha^2 + \alpha'^2 + \alpha''^2 = 1 & \alpha^2 + \beta^2 + \gamma^2 = 1 \\
\beta^2 + \beta'^2 + \beta''^2 = 1 & \alpha'^2 + \beta'^2 + \gamma'^2 = 1 \\
\gamma^2 + \gamma'^2 + \gamma''^2 = 1 & \alpha''^2 + \beta''^2 + \gamma''^2 = 1 \\
\beta\gamma + \beta'\gamma' + \beta''\gamma'' = 0 & \alpha'\alpha'' + \beta'\beta'' + \gamma'\gamma' = 0 \\
\gamma\alpha + \gamma'\alpha' + \gamma''\alpha'' = 0 & \alpha''\alpha + \beta''\beta + \gamma''\gamma = 0 \\
\alpha\beta + \alpha'\beta' + \alpha''\beta'' = 0 & \alpha\alpha' + \beta\beta' + \gamma\gamma' = 0
\end{array}$$

Besides which, each of the quantities α, α', &c. may be expressed in terms of the others, as follows:—

$$\begin{array}{lll}
\alpha = \beta'\gamma'' - \gamma'\beta'' & \beta = \gamma'\alpha'' - \alpha'\gamma'' & \gamma = \alpha'\beta'' - \beta'\alpha'' \\
\alpha' = \beta''\gamma - \gamma''\beta, & \beta' = \gamma''\alpha - \alpha''\gamma. & \gamma' = \alpha''\beta - \beta''\alpha \\
\alpha'' = \beta\gamma' - \gamma\beta', & \beta'' = \gamma\alpha' - \alpha\gamma & \gamma'' = \alpha\beta' - \beta\alpha'.
\end{array}$$

For the mode in which these nine quantities are made to depend upon three, we must refer to works on mechanics, in which such reduction is particularly useful. We avoid giving it here, because trifling differences exist in the manner of taking the quantities to functions of which all the rest are to be reduced, so that no set of equations can be given which can be called universal. So far as we have gone, the expressions of all writers are the same, though the letters used are not always alike.

TRANSFUSION OF BLOOD is the operation of transferring the blood of one animal into the blood-vessels of another, and is sometimes beneficially employed for reviving those who are nearly dying after severe hæmorrhage. The operation had long been used as a means of experiment, and in the vain hope that by injecting the blood of a healthy man or animal into the vessels of a diseased one, the health of the latter would be restored; but it had rarely been employed for its only useful purpose till Dr. Blundell, after a long series of well-conducted experiments on animals, proved that it might be safely and advantageously employed in men. His observations are published in his 'Physiological and Pathological Researches;' and since his revival of the operation, the lives of many persons have been saved who were, in all probability, dying from the loss of blood during or after surgical operations, during gestation, and in other circumstances. The operation has, indeed, often failed; it has often been unnecessarily performed; and its performance is not unaccompanied by danger to the patient; but still there is sufficient evidence of its high utility in cases which, without it, would have been quite or nearly hopeless, to warrant its being resorted to under the guidance of a sound judgment.

The chief instruments employed in the operation are a syringe, with double pipes, a basin of appropriate form, and a fine tube fixed on one of the pipes of the syringe. One of the veins of the arm of the patient being opened just sufficiently to admit the point of the tube, and fixed by a probe, blood must be drawn through a free opening in the vein of some healthy person, and as it flows into the basin must be slowly sucked up, without any mixture of air, by the syringe. When the syringe is filled and carefully cleared from all air by forcing blood up to the very point of the tube, the latter must be introduced into the patient's vein, and the blood steadily and slowly injected. Four or five ounces are often sufficient to revive a patient, and if they produce head-ache, flushings of the face, tendency to fainting, and other unpleasant symptoms, the transfusion should be arrested; but if not, the injection should be continued till it produces some good effect, or till a pint of blood has been transfused. Beyond this it is not safe to carry the operation, nor is it likely to be beneficial. A second or a third injection may be employed when the state of the patient seems to render it necessary.

The experiments of transfusing the blood of various animals into the vessels of man proved only mischievous; and those of transferring the blood of an animal of one species to the blood of another species are of too little interest and have produced too few general results to be worth recording here. The injection of various medicinal substances into the veins has been tried, but its effects are not sufficiently different from those produced by the ordinary mode of taking medicine, to render it advisable to submit to an operation which is itself dangerous. All the important facts relating to the subject may be read in an article on Transfusion, by Dr. Kay, in the 'Cyclopædia of Practical Medicine,' and in the works from which he quotes.

TRANSIT, or TRANSIT INSTRUMENT (*Instrument des Passages*), was invented by Römer about the year 1690. The description is to be found at page 47 of the 'Basis Astronomiæ,' by his pupil, Horrebow, Havniæ, 1735; and we recommend the perusal of this book, which contains an account of Römer's inventions and methods, to all those who, reading Latin with moderate ease, feel a desire to learn the origin of modern practical astronomy.

The object of the present article is to give such an account of the transit as will enable any one to use it with tolerable success. Those who wish for more perfect information must consult the introductions to the Greenwich, Königsburg, Dorpat, Cambridge, Edinburgh, &c., 'Observations.' Our type will be the *portable* transit-instrument, leaving the reader to accommodate what is here said to the powers of his own instrument, or to the practice of the Observatory which he adopts for a model.

There are three principal parts expressed in the cut. The iron stand, carrying the Y's with their adjustments; the telescope, inserted at right angles through an axis with a small vertical circle for finding or verifying stars; and the cross level. The stand is made of cast-iron, and should be of great strength, though perhaps that which is here figured would be found inconveniently heavy if the instrument is often moved. The Y's are contained in brass pieces, strongly united to the tops of the two uprights. The left hand Y has a motion up and down, which is given by a milled screw partially seen immediately under the pivot. The right hand Y is moved in azimuth by a screw, the milled head of which is seen projected upon the lantern. In portable instruments it is very convenient to have this lateral or azimuthal adjustment made by screwing against a spring, as it is in this instrument. In fixed observatories the adjustment is made by two antagonist drawing screws, one of which is tightened and the other loosened; and indeed this is the general construction of instruments of every size, and is the most solid fixture. But it is so convenient to be able to move the instrument at pleasure in azimuth while actually looking through the telescope, that we should strongly recommend the adoption of the counter-spring whenever the instrument is small, and is either to be frequently shifted, or is not furnished with a meridian mark. The spring must press pretty strongly against the screw, and there should be a clamping button in each adjustment, to keep all secure.

The axis is made of two strong brass cones soldered on the central sphere. The sphere is cast hollow with two shoulders, over which the cones slip. As this is the most important part of the instrument, great care should be taken of the fitting before the axis is finally put together, and the symmetry of the parts as to the centre should be perfect. If the instrument is weak here, it is utterly worthless. In the older English instruments the centre was a cube, and that form is frequently adopted at present by continental artists. The transit at Bruxelles, by Gambey, one of the largest and finest instruments in the world, is so constructed. The essential requisite, however, is *symmetrical strength*, and any shape is good which fulfils this condition. The pivots are soldered into the extremities of the cones, and are turned after the whole is fixed. One of them is pierced to admit light into the axis. In large instruments the pivots have an outer surface of steel, which is less affected by wear. Greater care is required to guard steel pivots from rust,* and the turning must be performed with a diamond cutter, as the hard knots to which steel is subject resist and jar the ordinary cutter out of its place. The pivots should be turned pretty nearly to the same diameter: the marks of the tool are ground off afterwards by collars which are made to fit closely on the pivots, and are changed and reversed from time to time. When the surface is perfectly formed, the grinding should be discontinued, as a small difference of size in the pivots is of little consequence, while an alteration of the cylindrical form of the pivots, or of the direction of their axes, ruins the instrument. The perforated or *illuminated* end of the axis is on the right hand pier in this figure. The light of the lantern shines through this, and lights up an annular plate in the centre, which makes an angle of 45° with the axis and with the telescope, and thus light enough is thrown down to the eye-end to illuminate the field very vividly, while the opening allows the rays from the object-end to pass without impediment. The quantity of light may be regulated by a contrivance for diminishing the aperture of the lantern, or by a shade passing between the lantern and the pivot. In some transits there is a contrivance for altering the angle of the central reflector in the body of the instrument; but this, although very handy, is objectionable, as affecting the symmetry of the instrument. In a thirty-inch transit the lantern is within reach, and may be twisted a little, so as to reduce the light at pleasure. The setting circle, with its level and clamp, are towards the illuminated end of the axis. The tail-piece, which is attached to the verniers and level, is held between the rounded ends of the two screws at *a*. By screwing one and loosening the other, the bubble of the level is brought to the middle, when the vernier points out the reading of the circle. There is a lens and reflector, for lighting and reading off the circle. The instrument here figured has a vernier which reads single minutes; but the vernier is inconveniently long for a fixed lens, and we should prefer reading to every 2′, which is more than sufficiently near for finding or identifying stars. If the small circle is carefully looked at, two out of three small screws are seen which fix the circle to the axis. When these are released, the circle will turn freely round. This contrivance will save some trouble when an instrument is used for a long time in the same place without reversing, but is scarcely worth being applied to one which is frequently shifted or reversed. The clamp for fixing the telescope in altitude and the slow-motion screw are seen at *b*. There is a caution to be given here. The tail-piece should never be tightly nipped, unless the instrument is used for observing declinations, and it and the tangent screw must be released when the observer uses the azimuth screw for bisecting any object, such as a mark or a star at a given moment. In large transits there are generally two small circles fixed on each side of the transit towards the eye-end. They are here more convenient for setting, and it is easy to pass rapidly from one star to another, when both the circles are previously set. There is great diversity in the graduation of the setting circles. In large instruments which are used for some time in the same position, it is best to make the verniers read polar distance or declination, re-adjusting the circles whenever the transit is reversed. With a portable transit, which is or ought to be very frequently reversed, a graduation to altitudes one way, which becomes zenith distances when reversed, is perhaps as convenient as any, though a slight computation for each star is required to form a working catalogue. The telescope in this instrument is not inserted in the ordinary manner. The central portion, from *c* to *d*, is in one tube,

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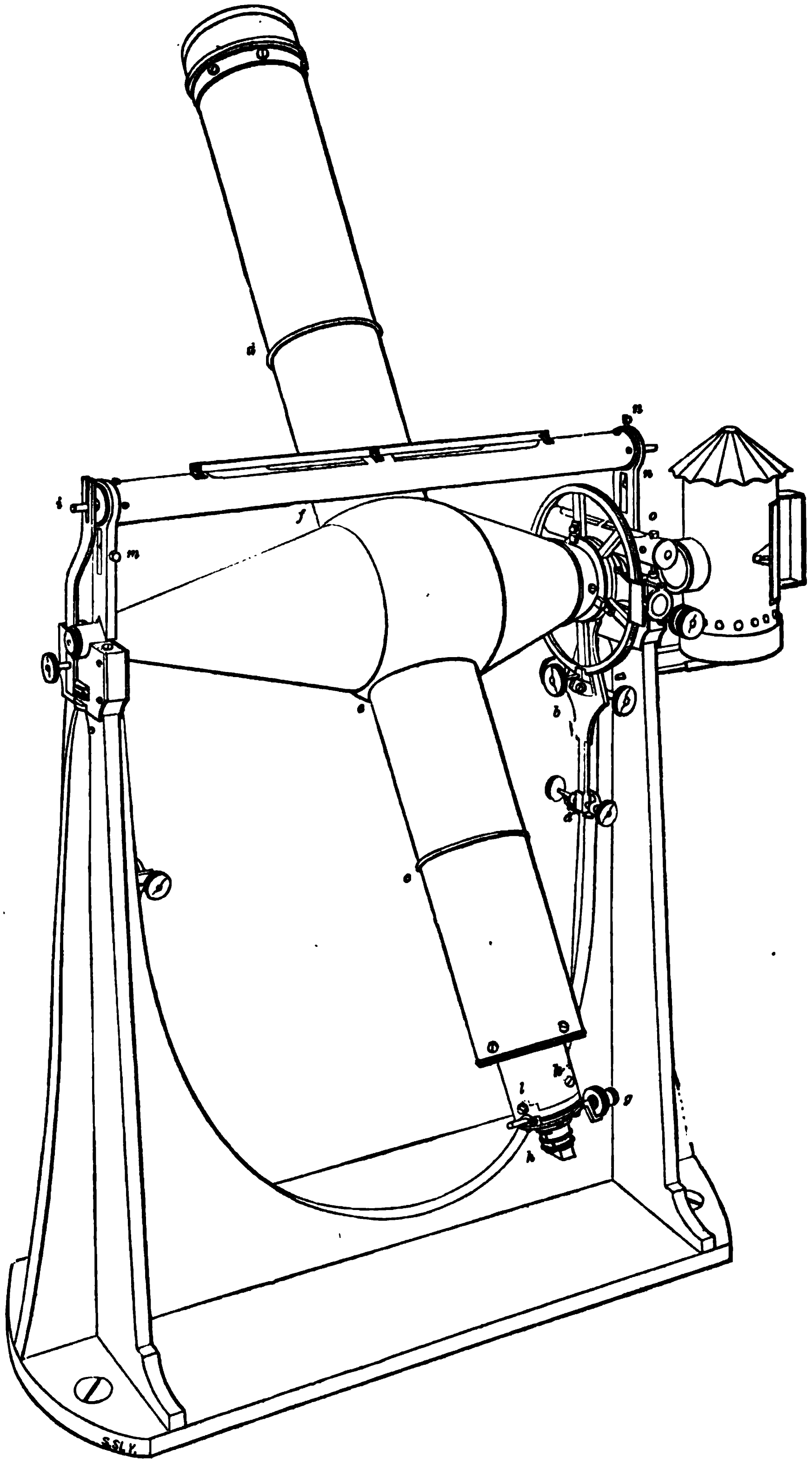
* When the instrument is small and frequently out of use, it should be removed from the Y's, and the pivots protected by caps which slip closely over them.



Transit Instrument.

pierced on the right side to allow the light to pass, and soldered at *e* and *f* to the central sphere. The reflecting plate is fixed in this telescope, and can be turned to throw the light up or down. The object-end and eye-end are screwed on at *c* and *d*, and are interchangeable. The telescopes are usually in two pieces, which are screwed into the central sphere at *e* and *f*. The advantage expected from the present construction is, that there is firmer screw-hold and less leverage for any blow or rough handling; and that by interchanging the object and eye-end, fresh portions of the pivots are brought into action, thus diminishing wear, and equalising minute errors of form or flexure. The object-glass of the telescope should be carefully selected, and of as large an aperture as will show a good image. The superiority of a large instrument over a small one is wholly in the increased optical power. In all other respects it is probably inferior, that is, if the support of the smaller instrument be as solid as that of the larger. There are seven fixed vertical wires at equal spaces, and two horizontal wires, between which the star is observed. The head of the micrometer is shown at *g*. A small prism for observing stars near the zenith is slipped on the eye-piece when required, as at *h*.

The level *rides* on the pivots with its Y's. There is a pin at each end, which drops into a fork at *i*, to hold the level safely and upright. This is completely seen at the left pier. At this end is the adjustment for setting the level tube parallel with the axis. At the other end is an adjustment for raising or depressing that extremity of the level. The level should be very sensible and of the same curvature throughout. The graduation we have found most convenient is to have the principal divisions to 15" and the subdivision to 1"·5, numbered as units and tenths, which, though erroneously, is briefly described by calling the units seconds of time. If this scale should be too fine for the level, a principal division to 30", and subdivisions to 3", but still numbered as units and tenths, will be found equally convenient. The riding level is generally applied to the instruments which are so large, and consequently the piers so high, that a man cannot apply the level safely while standing on the floor, and also to small instruments, of necessity, when they are clamped, as this is, to the pier. For a transit between stone piers which does not exceed five or six feet, we prefer a swinging level, which may be applied and read while standing on the floor.

When Troughton undertook, much against his will, to construct a ten-foot transit for the Royal Observatory, he adopted a very ingenious mode of uniting the cones and the telescope with the central sphere. The description will be found in the 'Phil. Trans.' for 1826, p. 423: that part which treats of the construction of the instrument is from Troughton's own pen. He also added four braces, to connect the telescope with the axis. We are not disposed to attach much value to this mode of connecting the axis and telescope, which, moreover, requires very accurate fittings. The braces are positively injurious, unless they are exactly and at the same moment exposed to the same temperature. It is said, indeed, in the memoir just mentioned, that when the antagonist braces were exposed to very different temperatures, the instrument continued to preserve its form. If so, the experiments simply show the centre-work to have been so strong that the braces could not disturb it, in which case they are merely useless. At Cambridge the braces were found to derange the instrument, and were consequently removed, to the great improvement of its steadiness.

There is no great difference of construction between different transits, except what we have already mentioned. It is desirable even for the smallest instruments that the supports should be of stone when they are not perpetually shifted about. The Y's then are separate pieces fixed by screws to plugs let into the stone. For small transits the stone may be in one or three pieces, according to the size. When practicable, the piers should be high enough and wide enough apart to let the observer stand or lie down between them. This saves perpetual meddling with the eye-piece, and the eye is less strained. We have already remarked that the performance of a well-made transit depends rather on the permanence of its fixing than anything else. It is to the greater care bestowed on the foundations of large instruments that much of their superior performance is to be attributed.

The principal use of a transit instrument is that of determining the exact moment when a celestial body passes the meridian of the place of observation. Now the meridian is a *great* circle which passes through the *zenith* and the *pole*, and the instrument is *adjusted* when the line of sight* is a portion of the meridian during the whole rotation of the telescope.

As in all other instruments, the telescope is first to be adjusted for distinct vision. Put on a tolerably high power, and slide the eye-piece out and in till you see the wires sharply without straining the eye. Then direct the telescope to a bright star or a double star; and if the image of it is distinct, the telescope is in focus. If not, release the screws at *k*, and draw the tube out or push it in until the image is as perfect as you can make it. There is another opposite screw to *k*, and the exterior holes allow a little play. Some trouble and guesswork may be saved by making two slight scratches on the eye-piece where the sight of the wires and of the star are respectively most perfect, and drawing the principal tube out or pushing it in this quantity. The operation has succeeded, if, in viewing a slow-moving star, like Polaris, there is no shifting between the star and the wire which bisects it, while the observer moves his head laterally. This adjustment is generally best made by the instrument-maker, and as it is not liable to alter, we should prefer to have the telescope tube cut the proper length upon his responsibility, so that the position of the wire is permanent. When this adjustment is completed, the telescope must be turned on some tolerably distinct object, which is to be bisected by the middle wire near the upper part of the field. If, on raising the telescope, it is also bisected at the lower part of the field, the wire is perpendicular to the axis; but if not, the tube is to be twisted without altering the focal length until the object comes half-way to bisection. The bisection is completed by the azimuth-screw, when the object ought to be seen bisected at the top of the field when the telescope is depressed. One or two trials will suffice for this purpose, and then the screws at *k* must be tightened.

The first of the principal adjustments is that of setting the line of sight at right angles to the cross-axis, when it necessarily describes a great circle. A distinct object must be selected not far from the horizon, and bisected by the middle wire, using the azimuth-screw. The axis is then carefully lifted out of its Y's, and returned end for end, or *reversed*, and the object viewed again. It is now to be bisected as before, half by moving the azimuth-screw, and half by the screw at *l* and its antagonist, each of which *draws* the plate on which the wires are fixed. The operation must be repeated until no difference can be seen in the bisection, whichever be the position of the axis. When there is a micrometer, the operation is somewhat easier. The micrometer wire is brought first on one side and then on the other of the centre wire, so as just to shut out the light between them, and the mean of these two readings is the reading of the zero point, that which corresponds to the exact superposition of the wires. The distinct object is bisected by the micrometer wire; and we will suppose that the screw has to be turned three revolutions for this purpose from its zero position. Now reverse the axis, and suppose the micrometer has only to be moved two revolutions from its zero to bisection. The half-way, or two revolutions and a half, is the distance which should be shown. Carry the micrometer wire two revolutions and a half back from its last position, and that is the position which the centre wire should occupy. If the joint thicknesses of the two wires (previously determined) equal ten parts, carry the micrometer five parts still farther back, and bring up the middle wire to touch it by the screws at *l* as before. The error of collimation is now corrected, as will be found by repeating the observation. The collimating screws have generally a capstan-head, which is awkward, and indeed dangerous so near the eye; and we think the square head, which is turned by a key, is more manageable. The screws should be drawn tight, but not forced. We have here followed the usual rule of directing the observer to select a well-defined object near the horizon. If the pivots of the axis are equal, the mark may be considerably elevated or depressed without introducing any error; and an object which is not very distant may be seen sharply defined when the aperture of the object-glass is diminished. In fixed observatories there is usually either a meridian mark north and south at a considerable distance, or two near marks, which are made distinct by interposing lenses. At Greenwich and Cambridge a south meridian mark is combined with a supplementary transit in the north slit; at Oxford two near marks are made visible by lenses fixed in the observatory slits. By using north and south marks at the same time, you are warned of any alteration in the Y's during the reversal, which, when the instrument is heavy, is always to be feared. Such shifting would cause the error of collimation to appear different according as it is taken from one or the other mark. In standard observatories the error of collimation is not actually corrected unless it is large, but measured by the micrometer, as we have described, and the effect thus allowed for by calculation.

When the illuminated end is west, and the telescope pointing south, let the middle wire *appear* to be 3·263 Revolutions to the right-hand of the collimating mark: as the telescope reverses, this means that the transit points 3·263 R. to the left of the mark, or to the *east*. Now reverse the telescope, the illuminated end is east, and suppose the middle wire still to appear to the right of the mark, but only 3·187 R. These observations are best made on a calm cloudy day; often, after rain, the mark, if distant, is seen sharply and steadily. If there were no error of collimation, the micrometer should give the same quantity at both observations, or ½ (3·263 R. + 3·187 R), that is, 3·225 R. The error in collimation, therefore, is 0·038 R., and the instrument points to the east that quantity when the illuminated end is west. The scale of the micrometer screw is known. Let one revolution correspond to the space an equatorial star would move over in 3^{s} of time; then 0·038 R. is the space which an equatorial star would move over in $0^{s}{\cdot}114$, which is set down as the error to be employed in calculation. Now the effect of an error of collimation is to make the instrument describe a parallel to a great circle, and distant from it by the collimation error. If the instrument points to the east of the south, it also points the same quantity to the east of the north, and a star above pole will pass the *apparent* before the *true* meridian. The correction, therefore, to be applied to the observed transit is +, and when the instrument is reversed will be −. The time which a star takes to pass between the two circles, or the *correction*, is equal to the $\frac{\text{error of collimation}}{\text{cos. declin. of star}}$, or, in the supposition we have made, is—

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* We shall speak at present as if there were only one fixed wire in the telescope, namely, the middle vertical wire. The subsequent modification will cause no difficulty.

$$*\ +0^{s}\cdot114 \text{ sec. declin. Ill. end West.}$$
$$-0^{s}\cdot114 \text{ sec. declin. Ill. end east.}$$

The sign changes for stars *sub polo*.

Recently a method has been devised for recording transits, founded upon the principles of electro-magnetism. The sidereal clock is made to break the electric circuit at regular intervals of one second, and by a process similar to that employed in Morse's telegraph, the effect is impressed on a recording apparatus in connection with the clock. The observer is also enabled to break the circuit at any instant between two successive beats of the clock, and to record the fact in its proper place upon the registering paper. Hence in determining the transit of a star, the observer breaks the circuit at the instant of the star's passing each successive wire, and the results are imprinted in their proper place upon the recording apparatus. The distance between one of such recorded results and the nearest second as imprinted by the regular break-circuit apparatus of the clock, will indicate the fractional part of a second corresponding to the instant of the star's passage of the wire. In this method the eye and the sense of touch are called into operation instead of the eye and ear, as in the usual method. It originated in the United States of America, where it has been practised since the year 1849. It has been subsequently adopted at the Royal Observatory, Greenwich, and also at Altona, on the Continent. The differences depending on personal equation are almost annihilated by this method, which is well adapted for recording the transits of a great number of stars within a short compass of time.

The next adjustment is to make the axis horizontal. If the poles of motion are in the horizon, the great circle which the instrument, freed from collimation, describes, must pass through the zenith. Put on the level, and bring the bubble into the middle. Now rock it a little to and from the observer, and see whether the bubble still remains in the same place. If, in pushing the level from you, the bubble runs towards the left hand, this shows that the level tube itself is set askew upon its support, and that the left end, being nearest the observer, is elevated by that motion above the right end. Screw the small screw seen at *m*, and release its antagonist (these are *pushing* screws) until a considerable rocking motion scarcely moves the bubble at all. There is generally a cross level, to show when the principal level is upright; and this should be brought to have its bubble in the middle, when the principal level has been adjusted as above. The fork in the present example serves the same purpose when the level itself has been carefully adjusted. To level the *axis*, bring the bubble of the level to the same reading at each end (the numeration of the division is supposed to begin from the centre) by the elevating screw at the left hand Y. Reverse the level and bring the ends again to the same reading, half by the elevating screw of the Y, and half by the two screws seen at *n*, which raise or depress the level tube in its supports. On returning the level to its first position, the bubble should still be in the centre; but if not, it must be brought there, half by the Y elevating screw and half by its peculiar screws; and the operation must be repeated till this is effected, that is, if the observer cannot or will not calculate the effect of a small error, which may easily be measured. If he can (and there are few observers at present who cannot), the process is pretty much as follows; the graduation being supposed to be units each equal to 15″:—

Illuminated end West. Telescope South. Altitude 45°.
Observer North.
Level.
East end of bubble, $4^{s}\cdot76$. West end, $5^{s}\cdot84$.

The level is now reversed end for end, and the two ends again read off:—

East end .	$5^{s}\cdot24$	West end	$5^{s}\cdot34$
Mean, East	$5^{s}\cdot00$	West .	$5^{s}\cdot59$

which is the reading which the level would show in both positions if *it* were in adjustment. Hence the west end is higher than the east by half † the difference, or $0^{s}\cdot295$. The level should be applied in reversed positions several times, and a mean taken.

Now let the telescope itself be reversed, and suppose the following entries of observations to be made:—

Illuminated end East. Telescope North. Altitude 45°.
Observer North.

East	$4^{s}\cdot93$	**West**	$5^{s}\cdot66$
	$5\cdot42$		$5\cdot19$
Mean East	$5\cdot175$	**Mean West**	$5\cdot425$

The difference is now $0^{s}\cdot25$, and the west end is consequently too high by half the difference, or by $0^{s}\cdot125$, a result which differs from the former (Illuminated end West) by $0^{s}\cdot17$. If the partial observations have been pretty accordant (we suppose $0^{s}\cdot17$ to be the mean result of a considerable number of observations), this difference between the values of the inclination, according to the position of the illuminated end, must be supposed to be owing to a difference in the pivots; and if so, a little consideration will show that to obtain the true inclination of the axis in the two positions, ¼ of $0^{s}\cdot17$ must be subtracted from the level error Ill. end West, and must be added to the error Ill. end East. The true level errors therefore are—

$$\text{Ill. West, } +0^{s}\cdot295-0^{s}\cdot042, \text{ or } +0^{s}\cdot253;$$
$$\text{Ill. East, } +0^{s}\cdot125+0^{s}\cdot042, \text{ or } +0^{s}\cdot167.$$

By the mean of a great many careful observations made when the temperature is steady * and the sky overcast, the difference of the pivots, if it exists, is to be ascertained, and the correction due to that cause is to be applied to the indication of the level.

The error of inclination in the axis being measured, the corresponding correction which is to be applied to the observations is thus computed: If the west end of the transit axis be raised, it is clear that the circle perpendicular to that axis will continue to cut the horizon at the north and south points, but will pass to the east of the zenith, from which it will be removed by an arc equal to the inclination of the transit axis. All the stars above the pole will therefore appear to pass too early, and those below the pole will pass too late; and if the inclination be 15″, the effect in *time* upon any star will be

$$\frac{\text{cos zenith distance}}{\text{cos declination}} \times 1^{s}.$$

Now the level graduated as we have described gives the inclination in parts of which 15″ is the unity; hence the corrections to be *added* to the observed times of passage of stars will be, using the previous example—

$$\text{Ill. end West} \quad +0\cdot253^{s} \times \frac{\text{cos. zen. dist.}}{\text{cos. declin.}} \text{ of star;}$$

$$\text{Ill. end East} \quad +0\cdot167^{s} \times \frac{\text{cos. zen. dist.}}{\text{cos. declin.}} \text{ of star.}$$

The above corrections, for errors of collimation and inclination, are purely instrumental, and, as the reader will perceive, do not require any celestial observation. Before proceeding to the third adjustment, that by which the great vertical circle now described by the telescope is made to pass through the pole, it will be proper to mention how transit observations are actually made, and then describe how this error is corrected or computed. The instrument is in or very near the meridian; a star on entering the field is placed between the two horizontal wires. It will then gradually travel through the field, describing a parallel to the horizontal wires, and passing over the vertical wires in succession. The observer looks at his clock a little before the star comes to the first vertical wire, and counting the beats steadily forward by ear, determines as well as he can the second and decimal of a second at which the star is immediately under the wire. He writes this down, counting all the time, and goes through the same process at each of the seven wires with which his instrument is furnished. When the star has passed all the wires, he looks again at the clock to see that his count is right, and then sets down the hour and minute corresponding to the last wire. The habit of mentally counting on to sixty while writing down the observation is easily acquired. The estimation of the decimal of a second at which the star is covered by the wire is a matter of more difficulty, and, with some persons, requires considerable practice.† The observer is to attempt to fix in his mind the places of the star with respect to the wire at the preceding and succeeding beat, and to divide the second in proportion to the two spaces. Thus if at 16^{s} the star is rather nearer the wire, before passing, than it is at 17^{s}, after passing, he sets down $16^{s}\cdot4$: if he judges the proportion to be less than one to two, he sets down $16^{s}\cdot3$; and so on. Finally, the mean of the observations over the seven wires is to be taken, which is to be used as the actual time of transit. It would be desirable that an observer should begin by learning to note the observation with considerable exactness, and if it may be, under the care of a practised guide; but the observation is so simple, that every one acquires the power who has the will to try; and we believe that, with a little experience, one observer is nearly as good as another.

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* The rotation of the earth requires the *apparent* place of a star to be increased by $0^{s}\cdot0206$. cos. latitude × sec. of *'s declination. This comes to the same thing as subtracting $0^{s}\cdot0206$ × cos. latitude from the collimation correction. In lat. 51° 30′ this $=0^{s}\cdot013$. The corrections for collimation become

$$+0^{s}\cdot101 \times \text{sec. dec. * Ill. end West.}$$
$$-0^{s}\cdot127 \times \text{sec. dec. * Ill. end East.}$$

† If the unit were 30″, the west end would be higher by the whole difference.

* By adding the two readings together, you have the length of the bubble, which, if the temperature is steady, will continue to be of the same value during the series, but will grow shorter by heat. The level should be exposed some time before it is used. The coherence in the values of the length is a proof of the goodness of the observations. If the bubble continue to be of the same length when the zero is changed it is probable that the curvature is uniform. After the level has taken the temperature of the air, about a minute should be given for it to settle after each application, but not more than two. The observer should learn to read the level rapidly and boldly, as the zero changes if a light is held near to it for many seconds.

† Success will depend a good deal on the definition and magnifying power of the telescope, and also on the sharpness of the wires and the beat of the clock. The advantage of a distinct audible beat is very often entirely overlooked by clock-makers who are not observers.

Before applying the transit instrument to actual observation, the adjustment of the level of the vertical circle must be examined, which we will suppose to read altitudes when the illuminated end is west, and zenith distances when the axis is reversed. Having levelled the axis approximately, bring the bubble of the small level to the middle by the screws at *a* which hold the tail-piece, fix these firmly, and then direct the telescope on some point, which is to be placed exactly on the horizontal wire if there is but one, or between the wires if there are two. Read off the vernier, which we will suppose to give an altitude of 4°. Reverse the axis and repeat the former observation; and now read the vernier, which we will suppose to give a zenith distance of 87°. The sum of these readings is 91°, while it ought to be 90°, showing an excess of ½ a degree in each reading. Now set the vernier at 86° 30′, clamp the screw at *b*, and, by the tail-piece screws at *a* bring the object to its proper place between the wires; finally bring the bubble of the small level to the middle by the antagonist capstan-headed screws, which are seen towards the end of the level at *o*. The instrument will now show true altitudes and zenith distances within 1′ if the operation has been nicely performed. When the vernier reads polar distances, the vernier must be set to the polar distance of a known star, the telescope brought to the star, and the bubble of the small level afterwards brought to the middle. The latitude of the place may generally be supposed pretty well known: if not, direct the telescope to the pole star, or δ Ursæ Minoris, when near their upper or lower culminations, or to the sun, or to any star which the observer can identify when it is nearly south or north. The altitude or zenith distance of a known object will give a latitude near enough for finding a star from its catalogued place, or for instrumental corrections.

We will now proceed to the azimuthal correction. If the time is known from any other observations, the middle wire of the transit may be made to bisect a star at the time when by calculation it should pass; and if this star be Polaris or δ Ursæ Minoris, the instrument will be very nearly in the meridian; but if the observer has nothing but a transit instrument and a chronometer, he must place it as near as he can guess in the meridian,* and level the axis pretty carefully. A moderate knowledge of the heavens will tell what known star is likely to pass soon; and the instrument having been set to the proper altitude (or sweeping for it), the observer must wait patiently till it enters the field. The observation is then made in the manner already described. If the star is near the zenith, this alone will give an approximate clock-error. Now compute the time a star near the pole or horizon should pass, and bisect the star by the middle wire at the computed time. If the error in the position of the instrument is too large to be corrected by the azimuth screw, the stand must be shifted bodily a sufficient angle, and the instrument levelled afresh. In two or three trials it is easy to get the error within command of the azimuth-screw; and the observer, if he dislike calculation, may continue getting his clock-error by a star near the zenith, and then bisecting a star near the pole or horizon at the calculated time with the azimuth-screw, until all stars, high and low, give the same clock-error. The instrument is then in the meridian, and the clock-error is the true one. This tentative process may however be considerably abridged by a little easy calculation, which we will proceed to explain.

The errors of collimation and inclination being supposed to be annulled, either by adjustment or calculation, the line of sight describes a great circle passing through the zenith and not far from the pole. On drawing the figure, and supposing the deviation to be to the east of the south and west of the north, it will be seen that the effect of the error is to cause all stars between the south horizon and the zenith to pass too early, as well as all stars *sub polo;* while stars between the zenith and pole pass too late. The effect upon the passage of a star is proportional to $\frac{\text{sin. zenith distance}}{\text{cosin. declination}}$ of star. If x be assumed to be the amount of the deviation to the east of the south, measured in units of 15″, and the latitude of the place and the declination of the star be denoted respectively by ϕ and δ, the correction to be *added* to the observed passage of each star in respect of the error of deviation is $\frac{\sin(\phi-\delta)}{\cos\delta} \times x^{s}$.† Now suppose two stars, s and s', to be observed, which differ a good deal in declination, and let the values of $\sin\frac{(\phi-\delta)}{\cos\delta}$ for these stars be p and p': then $s + px$ and $s' + p'x$ are the times at which the stars would have been observed if the instrument had been in the meridian. The interval therefore between their transits thus corrected (and also corrected for the rate of the clock, if necessary) will be equal to the difference of their right ascensions, which may be taken from the 'Nautical Almanac,' if the stars are contained in its list, or must be computed from some good catalogue, if they are not. Let the right ascensions of the two stars be α and α', and we have the following equation:—

$$(s' + p'x) - (s + px) = \alpha' - \alpha.$$

$$\text{or } x = \frac{(\alpha' - \alpha) - (s' - s)}{p' - p}*$$

If the value of a revolution of the azimuth screw is known, it is easy to correct for this error at once with considerable accuracy. If x exceed 1^s or 2^s, it must be reduced to those limits. Should x be negative, the deviation is to the west of the south.

The accuracy of the determination of x depends, *cæteris paribus*, upon the stars which are used for the computation, that is, upon the value of the denominator of the above fraction, which should be as large as possible. The most favourable condition is, that both stars should be near the pole, one above and the other below: δ Ursæ Minoris and Cephei 51 Hevelii present this combination. It is always desirable that one of the stars should be pretty near the pole—Polaris, if possible. If the instrument is nearly in the meridian, it is better not to touch the azimuth screw, but to determine the value of x by grouping the stars together, in which $\frac{\sin(\phi-\delta)}{\cos\delta}$ is nearly of the same magnitude with the same sign. The value of x may afterwards be used to correct each star separately, and the transits thus corrected will be very nearly such as *would* have been made if the instrument had been exactly placed in the meridian.

In fixed observatories the meridian error is obtained when possible from consecutive transits of Polaris above and below pole. The observations are corrected for collimation and inclination, and for the rate of the clock. If the times of passage thus corrected differ twelve hours, there is no meridian error; but if the difference is greater or less than twelve hours, the deviation may be computed thus: Let s and s' be observed times of upper and lower culmination, corrected for collimation, inclination, and rate: let α and α' be the apparent right ascension of Polaris, taken from the 'Nautical Almanac; x^s the deviation as before; $-p$ and p' the values of $\frac{\sin(\phi-\delta)}{\cos\delta}$ for Polaris above and below pole, which have different signs. Then, exactly as before, $s - px$ and $s' + p'x$ will be the corrected times of transit, and

$$(s' + p'x) - (s - px) = \alpha' - \alpha,$$

$$\text{or } x = \frac{(\alpha' - \alpha) - (s' - s)}{p' + p}.$$

When three consecutive transits are observed, there is no need of taking any account of the rate of the clock (which is supposed to go uniformly), or the change in right ascension of Polaris in the interval; only a mean is taken of the first and third transits, which is compared with the second. The difference between these, divided by $p' + p$, gives the value of x. The sign may be made out by seeing whether the passage from upper to lower culmination is too small, and from lower to upper culmination too large, when the deviation is to the west of north, and therefore to the east of south, and the correction is to be *added*, or *versâ vice*, when it is to be subtracted.† In well-regulated observatories Polaris is always observed when it is convenient, and often when it is not; and the right ascension of the star, as well as the position of the instrument, is deduced from these double transits. When the right ascension is thus perfectly known, single transits of Polaris may be safely used in combination with other stars, to determine the azimuthal error for those times of the year when the star at one of its culminations passes altogether unseasonably. It is assumed, in this method, that the position of the instrument is the same for twenty-four hours; or that it changes uniformly.

If the reader has fully understood what precedes, he will have no difficulty in comprehending the mode of observing and reducing the observations which is followed at Greenwich and our principal observatories; but the private observer cannot always command a site which is wholly to be relied upon, and very seldom can afford the time for such an uninterrupted series of observations as is required to give full effect to the system just described. The precautions to be taken will depend mainly upon the objects he has in view, but generally speaking, the private transit observer will do wisely to take the places of the principal fixed stars from the lists furnished by Greenwich, though he may subsequently modify the values *inter se* by his own observations. Having done this, it will be easy for him to fix any other object with perfect accuracy, or to determine his time most scrupulously, although the steadiness of his transit is not beyond suspicion, and his avocations or inclination should only allow him to observe by fits and starts. We shall proceed to show how he may proceed under different hypotheses.

If he has a distant mark or a collimating telescope [see COLLIMATOR] with a micrometer to his transit, he proceeds exactly as we have described above to measure the quantity and direction of the collimation, the quantity and direction of the inclination, and then observes away, only taking care to note as many standard stars as will give him a correct clock-error, and at least some so far apart as will enable him to detect his azimuthal error. If he observe one or two stars near the pole, so much the better. Now calling ϵ the correction for the clock at the mean of the time of the observations of standard stars; $s, s' s''$, &c., as before the observed times of transit, corrected for collimation and level as aforesaid; p, p', p'', &c., with their proper signs, the correcting factors of the unknown azimuth x; and a, a', a'', &c., the apparent right ascensions of the standard stars, he has the following series of simple equations:—

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* If a line be drawn from Polaris between the fifth and sixth stars of the Great Bear, and a point taken in this line about 1⅓° from Polaris, the transit directed to this point will scarcely be 1° from the meridian. With a little practice one may come nearer than this at once.

† Throughout we shall assume the latitude to be north: when the declination is south, the sign of δ is changed, and $(\phi-\delta)$ becomes $(\phi+\delta)$. North of the zenith the numerator is negative, and the correction is to be subtracted between zenith and pole. Below the pole the cos δ becomes negative (reckoned through the pole), and the correction becomes additive, as at first.

* Substituting for p' and p their values, the denominator of this fraction $= \frac{\sin(\phi-\delta')}{\cos\delta'} - \frac{\sin(\phi-\delta)}{\cos\delta} = \cos\phi\,(\tan\delta - \tan\delta')$ or $= \cos\phi\,\frac{\sin(\delta-\delta')}{\cos\delta\cos\delta'}$. This last is the usual form for computing the azimuth by a high and low star.

† To prevent mistake, we shall always speak of the quantity which is to be applied to the observation to make it correct.

$$\begin{gathered} s+\epsilon+px=a \\ s'+\epsilon+px'=a' \\ s''+\epsilon+px''=a'' \\ \text{\&c.}\quad\text{\&c.}\quad\text{\&c.} \end{gathered}$$

Group together the equations in which the coefficient of x is nearly of the same magnitude and with the same sign,[*] and dividing each group by the number of its component parts, so as to have ϵ with unity as a coefficient, form at least two equations in which the coefficients of x differ considerably, and subtracting one from the other, a value of x will be found with its proper sign. Substituting this value of x in each of the equations $\epsilon=a-s-px$, you will have as many values of ϵ as you have equations; and taking the mean of those which are derived from the quick-moving stars, you have a good clock correction. Now if any other objects have been determined, the right ascension of which is required, add (speaking algebraically) the sum of all the corrections for collimation, inclination, declination, and clock-error to the observed transit, and you will have the *apparent* right ascension.

But it most frequently happens that the observer has no collimating mark and no micrometer to his instrument; nay, he may only have a view out of a window[†] which commands no distant or distinct object, and not be able to see even the zenith, much less the pole. This last is the greatest objection; for the accuracy of the meridian adjustment depends chiefly upon getting stars near the pole. To detect the error of collimation the observer must proceed thus:—After having carefully determined the inclination of the axis, he observes as many well-known stars as he can, especially getting them as high and as low as possible for ascertaining azimuthal error. He must then reverse the axis, repeating the measurement of the inclination, but by no means touching the elevating screw of the instrument, and make a similar set of observations. A series of equations must be formed for each position of the instrument, which will be of the following form:—supposing $s, s' s''$, to be the observed transits of the stars corrected for inclination *only; $q, q' q''$*, to be the values of the secant of declination for each star respectively; c, the unknown value of the collimation error in the first position (which becomes $-c$ when the instrument is reversed); x, the error of deviation; and ϵ the clock correction,—

$$\begin{gathered} s+\epsilon+qc+px=a \\ s'+\epsilon+q'c+p'x=a' \end{gathered}$$

and so on, for the stars first observed, and

$$\begin{gathered} s''+\epsilon-q''c+p''x=a'' \\ s'''+\epsilon-q''c+p'''x=a''' \end{gathered}$$

and so on, for the stars of the second set after the instrument is reversed.

The mode of treating these equations will differ according to circumstances. They might be solved by the method of least squares; but it is scarcely worth while in ordinary cases to use any such refinement. Form four groups, two in each set, those in which x has the largest, and those in which x has the smallest coefficients, dividing each group by the number of its component parts, so as to leave ϵ with unity for its coefficient. Call these equations 1, 2, 3, and 4. Subtracting (4) from (1), we shall eliminate ϵ, c will have a + coefficient exceeding 2, and x in the most difficult case, that is, when the observer can only look to the south, has a small positive coefficient. Again subtracting (3) from (2), we shall have c with a positive coefficient exceeding 2, and x with probably a small negative coefficient. From these two equations c can be determined pretty accurately. Substitute this value in equations (1) (2) (3) and (4), group (1) and (3) together, and (2) and (4) together, and we have a pair of equations in which x has coefficients considerably unequal; and by subtracting one from the other, ϵ is eliminated and x determined with tolerable accuracy. Finally, the substitution of these values of ϵ and x in the original equations will give a satisfactory clock-error if the observations are good and pretty numerous, even although the observer has not more than 50° of clear sky to work upon. The times of transit of other objects must be corrected by the quantities thus found, and in this way apparent right ascensions may be deduced with considerable certainty.

The clock correction should evidently come out the same in both positions of the instrument, and the differences from the mean fall within the ordinary errors of observation. If this is not the case, and there should be reason to fear any alteration in the position of the stand or the Y's in the process of reversing, the values of x cannot be assumed to be the same in both groups. If the time should be required with extreme accuracy from such imperfect observations, the observer may alter the quantity of collimation in his calculation till he does get the same clock-error, although with different deviations, from both sets. This may be done by one or two trials, but generally speaking the mean of the clock-errors from both sets will be near enough, and not differ sensibly from the more elaborate calculation. It is not however easy to get the time *very satisfactorily* without being able to see the pole, or at least the zenith.

In what precedes we have supposed the extreme case, that is, that nothing is to be seen north of the zenith, and that x therefore has always the same sign. The intelligent reader will be guided in practice, not by the directions here given, but by the *value of the coefficients of his unknown quantities*, a discretion which some astronomers cannot or will not use.

It is always desirable that the value of the three transit corrections should be small (indeed the formulæ are not exact, when the errors are large), to save unnecessary trouble in multiplying. The method of measuring the inclination implies that you can rely on the scale of the level for the quantity measured, which is scarcely true when the amount exceeds a few seconds of space. The collimation error is easily brought within reasonable limits, if the observer has a micrometer, or can see any fixed object distinctly while he alters the screws. The azimuthal adjustment requires either an object of reference, which is always the case in principal observatories, or adjusting-screws of which the thread and value are known, but this can only give correct results when the load upon the Y is inconsiderable. Portable instruments, which are really carried about and stuck at times out of a window, ought to have the spring to the azimuth-screw such as has been described.

It is convenient that the clock should be a little slow and have a small losing rate, the corrections for error and rate are then additive: if the west end of the axis be the higher and the deviation to the east of the south, the correction for these errors will also be *additive* to the observed transits of the greater part of the stars observed.

In most cases, the determination of the absolute time at the place is wanted, and this cannot be got without the level or some equivalent which tells how far the instrument swerves from the zenith. But where it is merely required to observe in a meridian, as in observing for a catalogue, it is more expeditious to change the form of the corrections. The two factors $\frac{\cos(\phi-\delta)}{\cos\delta}\times$ inclinat. $+\frac{\sin(\phi-\delta)}{\cos\delta}\times$ deviation may be expressed by a correction of this form: $m+n\tan\delta$, where m and n are two constants to be determined by observation.[*] In this case the stars should be observed in zones, and when the sweeps are not near the pole, it is easier to destroy the error of collimation by adjustment very nearly than to allow for the error. The secant of declination varies very slowly, and may be considered as a constant for the whole sweep, within moderate limits, and for a small value of the collimation, which may easily be reduced to 0ˢ·1 at once. Suppose an observer to have this purpose: he observes a large set of stars nearly at the same declination, taking care to have as many standard stars as possible above and below the limits of his sweep, and it is proper to have several with contrary declinations. Now calling the observed times of transit s, s', &c., he forms the following equations with standard stars:—

$$\begin{gathered} s+m+n\tan\delta=a \\ s'+m+n\tan\delta'=a' \end{gathered}$$

and so on. From these he composed two equations, one formed of all those in which $\tan\delta$ is positive and another in which $\tan\delta$ is negative, and which therefore may be represented thus:

$$\begin{gathered} \Sigma+m+n\mathrm{T}=\mathrm{A}. \\ \Sigma'+m-n\mathrm{T}'=\mathrm{A}'. \end{gathered}$$

from which n is found $=\frac{(\mathrm{A}-\Sigma)-(\mathrm{A}'-\Sigma')}{\mathrm{T}+\mathrm{T}'}$.

Substituting this value of n in the mean of the two equations, we

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[*] If two known circumpolar stars, like δ Ursæ and Cephei 51 Hevelii, are observed, subtract one of these equations from the other, and you have an equation in which x has a large coefficient, and therefore a good determination; if Polaris is well observed, use it singly, and group the standard stars together which have not more than 30° or 40° declination.

[†] This was the case with Römer, and the transit instrument was invented precisely for such a situation. See 'Basis Astronomiæ,' cap. 8.

[*] If i be the inclination as given by the level and x the deviation, then expanding the numerators, the sum of the corrections

$$=-=\frac{i(\cos\varphi.\cos\delta+\sin\varphi,\sin\delta)+x(\sin\varphi.\cos\delta-\cos\varphi.\sin\delta)}{\cos\delta}$$

$$=i\cos\varphi+x\sin\varphi+(i\sin\varphi-x\cos\varphi)\tan\delta$$

which agrees with the formula given above, putting

$$\begin{gathered} m=\iota+i\cos\varphi+x\sin\varphi \\ n=i\sin\varphi-x\cos\varphi \end{gathered}$$

The formula is easily deduced by drawing a figure and referring the transits to the meridian which cuts the equator at the same point as the circle described by the telescope.

have the value of *m*, and that with great exactness, if the stars have been well selected, are pretty numerous, and have been tolerably observed. To reduce the transits of the other objects observed to apparent R. A. nothing more is required than to add $m + n \tan \delta$ to the observed transit, which, besides being a good deal shorter than the method previously described, only requires a table of natural tangents for computing the corrections.

If the observations are made on or near the pole, where the sec δ varies almost as rapidly as the tangent, a sensible error of collimation would mix itself up in the value of tan δ. If the pivots of the instrument are exactly equal, two series might be observed in reversed positions of the axis, and as *m* and *n* would have the same value in each, while the sign of collimation changes, the determination of the latter would present no difficulty. We have used another plan, which in steady weather, when observations can be made on consecutive nights and in large masses, is perhaps the best for cataloguing. On the first night observe forty or fifty stars, consisting of all the standards which pass and those stars the places of which you wish to determine. These may now lie scattered all over the heavens, so far as the method is concerned. On the following evening reverse the instrument and observe the same stars. The first night, each observed star should be increased by $m + n \tan \delta + c \sec \delta$, while the second night the correction is $m' + n' \tan \delta - c \sec \delta$, the collimation being supposed (as is found to be the case) to be invariable in a well-made instrument, unless violence is used. Now if we add the observed transits of each star on the two nights together, and take a mean, the result requires a correction of $\frac{m + m'}{2} + \frac{n + n'}{2} \tan \delta$; and the collimation is eliminated. This new correction for the mean of the two nights is exactly of the same form as the original correction, call it $M + N \tan \delta$, and M and N are found by comparing the observed places of the standard stars with their known computed places, just as before. If the clock rate is sensible, the values of M, preceding and succeeding the mean of the standard stars, must receive a proportional correction, but it is easy to make the rate of a good clock so small that in ordinary circumstances this may be neglected. The rate may be determined near enough by observing the same high star both nights in the same position of the axis, and measuring the inclination by the level. From some trials of this method, we should strongly recommend it in a steady climate and where a large catalogue of stars is to be formed. An error of $0^{s}\cdot1$ would, we are convinced, be very rarely found in the R. A. of stars so determined within 40° of the equinoctial; the computations are very short and can scarcely be wrongly made, and there is only one computation of a mean place for two complete observations of an apparent place. Writing the separate results under each other, is an excellent check against those provoking small errors which, when they once get admittance, are so difficult of detection. It is a drawback that the computation does not furnish the absolute time or clock error, if that should be required for other purposes, without further calculation.

In this climate it frequently happens that the star is visible during only a portion of its passage over the wires, or the observer may lose some of the wires; hence it is necessary to have some means of completing the imperfect transits, and ascertaining so far as possible at what time the star would have passed the *mean* of the wires, if all could have been observed. For this purpose a sufficient number of complete and satisfactory observations is selected (suppose the illuminated end to be west), and the difference taken between each wire, and the mean of the wires. Multiplying these numbers respectively by the cosine of the corresponding star's declination, we have the differences, such as they would have been if the stars observed had been in the equinoctial. A mean of these is taken for each difference, and the proper sign affixed. If a second series be selected of observations made when the illuminated end is east, and be treated similarly, nearly the same values will be found as before, but in reversed order, and with different signs. A mean is taken when the number is sufficient to give a satisfactory result; and the logarithms of the intervals between each wire and the mean, for an equinoctial star, are set down for future use, discriminating whether the instrument is Illuminated end E. or W. Now suppose a broken set of wires is to be made up: take the logarithms with the proper sign corresponding to each wire, add to each logarithm the log. secant of the star's declination, and take the natural numbers corresponding to the logarithms thus found, and you have the number of seconds and decimals of a second which are to be *added* (algebraically) to the observation of each wire to reduce it to the mean wire. Of these partial results, a final mean is taken. The numbers for reducing each wire to the *mean wire* are found in the introductions to all the modern observations.

The slow-moving stars, such as Polaris and δ Ursæ Minoris, are those best suited for determining the interval of the wires, and this is one of the first points to which an observer should direct his attention, for he will observe a slow star as well at starting as afterwards, and as he will probably make a good many broken transits, the sooner he acquires the means of reducing them the better. The declination of these stars is perfectly known for every day from the Nautical Almanac, but there is a precaution to be taken here, which is unnecessary with quick-moving stars, as the path of the star being sensibly curved in moving from the outer to the inner wires, the motion between the wires is not uniform. The exact formula is

$$\text{sin distance of any wire from mean} = \text{sin time from mean} \times \text{cos. declin. star};$$

and the equatorial interval may be computed by taking the log sin of the intervals ÷ log sin 15″, instead of simply the log interval in seconds of time, as in other stars. Or if the following quantities be first subtracted from the intervals observed, the ordinary rule may be followed :—

Interval Observed.	Correction.	Interval Observed.	Correction.
4^{m}	$0^{s}\cdot0$	21^{m}	$1^{s}\cdot8$
8	0 ·1	22	2 ·0
12	0 ·3	23	2 ·3
13	0 ·4	24	2 ·6
14	0 ·5	25	2 ·9
15	0 ·6	26	3 ·3
16	0 ·8	27	3 ·7
17	0 ·9	28	4 ·2
18	1 ·1	29	4 ·6
19	1 ·3	30	5 ·1
20	1 ·5		

This table may also be used when the broken wires of a close circumpolar are to be reduced. Compute the correction for each wire by the ordinary formula, and add to it the number from this table corresponding to the interval, before applying the correction to the observation of the wire.

As the stars *sub polo* pass the wires in a contrary direction, the numbers for reducing each star to the mean wire must be taken from the table corresponding to the reversed position of the instrument, or, what comes to the same thing, they must be reckoned backward with changed signs from the table which belongs to the existing position. When the interval between the mean wire and the other wires is well established, the collimation error must be referred to the *mean* wire after it has been measured for the *middle* wire. There is a way of measuring the collimation, when the distance of each wire from the mean is well determined, which is very useful in the absence of a meridian or collimating mark. Polaris or δ Ursæ Minoris, or any slow-moving star, is observed over the first four wires (the inclination error having been previously measured); the instrument is then reversed and the star is observed over the remaining three wires, and the inclination again measured. The first set of observations is reduced to the *mean* wire by the known intervals at the horizontal position of the axis. The second set is similarly reduced to the mean wire, at the horizontal position. The difference between the two results, if the Y's have not been altered by lifting the instrument and setting it down again, is the sum of the collimation in two positions; and when this is divided by twice the secant of the star's declination, the result is the collimation error required. If the pivots are perfectly equal, the levelling may be omitted except as a precaution against altering the Y's. When the time is wanted with great nicety, it is convenient to observe a series of stars before reversing upon Polaris or δ Ursæ Minoris, and a second series after. If the pole star has been properly observed and reduced, and the collimation rightly determined, the two series will give nearly the same clock-error, and be a check on each other. The instrument must always be used in reversed positions, for determining the time, when this is practicable.

There is a curious anomaly sometimes found in transit observations, namely, that two practised observers will make a notable and constant difference in observing the exact moment at which a star passes a wire. Maskelyne first noticed this singularity in his assistant Kinnebrook, who observed a star $0^{s}\cdot7$ later than the Astronomer Royal. Bessel and Argelander have a still larger difference; and we found, on determining the longitude of Bruxelles chronometrically, that M. Quetelet, the director of that observatory, noted a transit about $0^{s}\cdot8$ earlier than Mr. Henry, one of the transit observers at Greenwich: so that if the time at each place had been simply taken from their observations without any allowance, the longitude would have been erroneous on that account *alone* $0^{s}\cdot8$, which might have been either way. This shows how insecure all nice chronometrical longitudes are, unless the same observer determines the time at both ends of the arc, or unless the relative *personal equation* of the observers at each end is carefully determined. [EQUATION, PERSONAL.] It would be advisable perhaps, where the result is very important and the distance considerable, to *reverse* the observers, as it seems that fatigue will, in some cases at least, cause a variation in the personal equation, and that two observers may begin a night with one difference and end with another.

If it were not for this latter circumstance, it would perhaps be possible to train observers to observe alike, by exhibiting the same phenomena of sound and sight (the relation between which might be established mechanically) to a class, and habituating them, like an orchestra, to keep the same time; and such a piece of mechanism would be easily made, though there would be a difficulty in getting observers to submit to the drill. We have found the following practice a good exercise for making the eye and ear work together. The pointer of a clock, with dead-beat scapement, springs forward simultaneously with the sound of the beat. Where there is a good deal of noise, and the clock has a low beat, it is found necessary to have a second clock called a journeyman, which strikes loudly and speaks as it were for the transit clock. The observer makes them beat pretty nearly together, and then listening at the principal clock and noting the difference, he either pushes forward or delays the pendulum of the journeyman to make the coincidence perfect, and this ought to be continued until he cannot distinguish between the two beats when standing close to the transit clock. Let a person try to make this coincidence by *looking* at the transit clock and *listening* to the journeyman, and if he can, or can very nearly do this, it is evident that he notes an appearance at the time it happens. Perhaps by trying the same thing when fatigued, he might detect a change in his perceptions, for the coincidence of sounds, as judged of when equalised by standing near the weaker source, is one in which a tolerable ear can scarcely be more than $0^{s}\cdot01$ or $0^{s}\cdot02$ out at farthest.

The position of the horizontal axis has been all along supposed to be measured by the level, and this is certainly the most ready method. But the level may happen to be broken, or, unless it comes from a very careful maker, it may be sluggish, or unequally divided. The beautiful levels which accompany Ertel's instruments, which are covered at the ends with parchment and filled with ether, are very liable to leak, as we know by experience. In such a difficulty, our celebrated surveyor Captain W. F. Owen raised a tall pole, and having put thereupon a distinct mark, adjusted his instrument by moving the elevation screw until the wire passed through the mark seen directly and by reflexion. In another instance, where the level was broken, an observer of some name was unable to supply its place, and a projected set of observations failed in consequence. The simplest method is that pursued by Captain Owen, substituting the pole star or other slow-moving star at its culmination for the tall pole. When the axis is thus *nearly* corrected, which may easily be done when the star passes the first wire, it is better to observe the star over the rest of the wires half directly and half by reflexion, and to reduce each set to the mean wire. On drawing the figure it will be seen that any error of level will affect the transit of a star seen directly one way, just as much as it will affect the transit of the same star, seen by reflexion, the other way, or that the difference of the two transits, after each set has been reduced to the mean wire, is twice the error due to inclination: that is, the difference of the transits in the two positions is, when the star is above the pole $= \dfrac{2\cos(\phi-\delta)}{\cos\delta}\times i$, from which i is determined, and may be used for all the other observations. The observation will succeed very well with any slow-moving star, if the observer has time to shift from one position to the other without hurry; or he may use two high stars, each observed over all the wires, if they have the same altitude, or if he should happen to know the other errors of his instrument. Indeed, if he has no objection to solve simple equations with four unknown quantities, he may proceed exactly as we have shown in former instances, introducing another term with i and its coefficient, and changing the sign for the observations by reflexion.

Observations by reflexion of Polaris are well suited for another purpose, namely, for examining the value of the level scale by means proper to the instrument itself. Raise the west end until the bubble is nearly at the west end of the scale, and by a mean of half a dozen readings, reversing each time, ascertain the error of inclination. Now observe Polaris exactly as we have before mentioned, or, if the observer likes better, directly over the 1st, 2nd, 6th, and 7th wires, and by reflexion over the 3rd, 4th, and 5th; reduce each set to the mean wire, and calculate by the formula already given the true inclination of the axis. On a following night repeat the operation, the illuminated end being on the same pier, only lowering the west end of the axis until the bubble is nearly at the east end of the scale, and get as before two values for the inclination, one from the scale, and another by observation. Take a mean, and you will have the true value of the parts of the scale. If the result varies much in the two experiments, it shows either that the curvature of the level is unequal, or that one pivot is thicker than the other. This may be ascertained by the level alone, as we have shown above, or would be indicated by a difference between the direct and reflected observations when the axis is horizontal by the level, or by comparing the inclination obtained from reflexion in the manner last pointed out, in reversed positions of the instrument, supposing the Y's not to change during the experiment. Thus if the inclination be determined by observing Polaris over the first half of the wires directly and the second half by reflexion, a value of the inclination will be found. Reverse the instrument, and make the same observations upon another slow-moving star, and you will have a second value of the inclination, which should agree with the former if the pivots are equal; half the difference, if it exists, is the difference in the radii of the pivots. The level however affords a much easier, and, we believe, better measure of inequality; but it will not show if the pivots be elliptic, which the observations by reflexion would do if stars at different altitudes were observed. If the two tests agree, it is a reason for believing that the pivots are round within the limits of these very searching experiments. But as we believe these observations have never yet been made, it would be useless to expatiate further upon their possible advantages. The late astronomer royal, Mr. Pond, tested the transit at Greenwich by observing a set of stars directly and a second set by reflexion after the axis had been most carefully levelled, and found that on reversing his sets on a subsequent night he got the same mean interval, as he ought. Professor Woodhouse examined his level scale by observing Polaris over half the wires with one end high, and the other half with the other end high. This is less sensitive than the method we have pointed out, but will do for its purpose very well, if the instrument is examined and verified by a meridian mark between the first and second set of observations, otherwise we should be afraid a change in azimuth might be caused by turning the elevating screw, in spite of all the care of the artist to prevent it.

An eye-piece has been introduced into use within the last few years, which, by illuminating the wires in a particular manner, enables the observer, looking downwards into a basin of mercury, to see at the same time the wires and their reflected image: if these be made to coincide, the telescope is vertical, and therefore the axis horizontal. If the micrometer wire be used to measure the interval, the result will be found to be twice the inclination.

The transit may be levelled, as it was in older times, by a plumb-line, which, hanging from a frame placed close to the instrument and in front of it, is made to pass over two dots, placed at the eye and object end of the telescope. This is an accurate but intolerably troublesome method. In Groombridge's circle, Troughton used a plumb-line in a tube at right angles to the axis and to the telescope for the same object. The images of the opposite dots at top and bottom were thrown on the line by lenses, and viewed through microscopes, in the way in which he always applied the plumb-line. We do not know whether Mr. Groombridge adjusted the horizontal axis by means of this plumb-line or no, but the artist himself said that he introduced the tube principally to make the axis equally weak all round, finding that it was previously so much stronger in one direction than another as to give him trouble in dividing it. Finally, the axis may be adjusted, or the inclination measured micrometrically, by means of a vertical collimator, which is convenient enough, but, so far as our own experience goes, rather uncertain in its indications, and much inferior in *both respects* to a good level. A really good level carefully and frequently applied will show the position of the transit axis to about $0''\cdot2$ or $0''\cdot3$, or the inclination correction to $0^{s}\cdot02$, and this is a smaller quantity than a considerable number of careful observations will show.

From what we have already said, it is evident that where exact time is wanted, the collimation, inclination, and deviation factors are perpetually required. The collimation factor is merely a table of secants of declination, and may be taken from any table of natural secants. The inclination and deviation factors should be computed for each observatory to every 10′ of declination, and be tabulated for constant use. For the stars often observed, we find it most convenient to have a catalogue in which the log secants of declination, the natural secants and tangents of declination, and the factors for inclination and deviation, are entered in parallel columns with the proper signs. The astronomer royal employs a sliding-rule for these and similar computations. In computing this table for a given latitude, the formulæ will be advantageously transformed thus:—

$$\text{Inclination factor} = \frac{\cos(\phi-\delta)}{\cos\delta} = \cos\phi + \sin\phi\tan\delta;$$

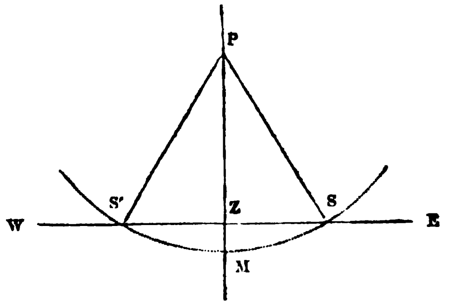
$$\text{Deviation factor} = \frac{\sin(\phi-\delta)}{\cos\delta} = \sin\phi - \cos\phi\tan\delta:$$

so that having the natural sine and cosine of latitude, and also the log sine and cosine, the computation reduces itself to adding the log tan. declination to these last. The necessary tables may be computed in a few hours as far as is advisable; for near the pole the change of declination has so large an effect, that it is necessary to use the exact declination.

Great service would be done to amateur practical astronomers by a judicious set of printed forms, in which to enter and reduce their observations; and by a set of tables sufficient for these small computations, and not containing anything further. This can only be obtained by repeated attempts, and after all most observers would probably prefer a modification of some form, to adopting it implicitly. We have tried to produce something in this way on which a better attempt may be founded. The astronomer royal published a portion of the forms used at Greenwich in the volume of the Observations for 1840, and we venture to recommend his practice to other observers, in order that their less able brethren may profit by their superior skill and experience.

While he was employed in the Royal Observatory of Paris, Römer proposed a method of determining the equinox by observing the azimuth of the sun at rising and setting near the time of the equinox, which method he illustrated by an example. ('Basis Astronomiæ,' p. 107.) He thus got rid of the effects of parallax and refraction, and deduced an accurate declination of the sun without an exact knowledge of the latitude. The method is a very good one, though undoubtedly inferior to that proposed and executed by Flamsteed. Many years after, Römer, on erecting a small observatory in his own country, placed a transit east and west, that is, in the prime vertical. Almost all his papers were destroyed by a great fire at Copenhagen, and it does not seem by Horrebow's account that any use was made of this prime vertical transit. He intended probably to observe the sun in the prime vertical for the purpose already explained; but as he had now a meridian transit circle, with which he could measure declinations with great accuracy, he seems not to have followed up this idea. Bessel, in the 'Astronomische Nachrichten,' vol. ii. p. 9, showed that the transits of stars over the prime vertical near the zenith might be employed for determining differences of latitude with great accuracy; and since that time several observatories abroad have had transits erected in this position. We shall here briefly show how terrestrial latitudes and differences of latitude may be determined by a transit in the prime vertical.

Let P be the pole, Z the zenith, EZW the prime vertical, which is also the line described in the heavens by the transit, and SMS′ part of the daily parallel of a star which passes south of the zenith and near to it. Then if the time at which the star is on the wire at S and S′ be noted, the angle SPS′ is the difference of those times, and therefore known.



In the right-angled triangle ZPS,

$$\tan PZ = \tan PS \times \cos SPZ;$$
$$\text{or, } \operatorname{cotan} \phi = \operatorname{cotan} \delta \times \cos \tfrac{1}{2} \text{ time elapsed.}$$

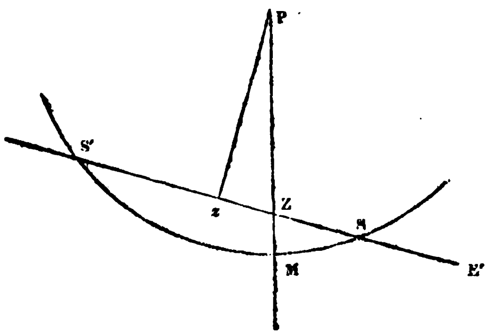
If then the declination of the star is known, the latitude is found; or if the same star be observed at two places, the difference of latitude may be found with only an approximate knowledge of its place.

Again, if the same star be observed regularly at the same place, as tan declination = tan latitude × cos ½ time elapsed, and as the time elapsed can be observed with the greatest nicety, the *variations* of declination can also be measured with great precision. Thus the constants of aberration and nutation may be determined by a transit in the prime vertical instead of a zenith sector; but the advantage appears to us questionable. The telescope in a zenith sector may be of almost any size, which gives it an immense advantage over the transit. The level may be applied just as well to one instrument as the other (the plumb-line much better to the zenith sector;) and though the division by time in the transit is more perfect than division by arc in the sector, the telescopes being of the same power, it is certain that the division is not the failing part of the sector. An error in the form of the pivots would be injurious to the transit, and is not readily to be detected: but of little consequence in the sector, and easily detected. It must, however, be admitted, in returning from this digression, that the zenith sector has not quite equalled the expectations which might be formed of it; and that the modern transit, as it comes from the best makers, is an almost perfect instrument.

In determining the latitude by the portable transit, it is easy to place the instrument with sufficient accuracy, for the error must be considerable to affect the result very sensibly. An object-glass may be inserted in one pivot, and wires and an eye-piece into the other, and the telescope be directed upon a mark placed in the meridian by the instrument used in the ordinary way. This would possibly suit most observers best. Ertel of Munich (and many other continental artists) makes an astronomical theodolet, which is particularly adapted to this observation: the divided horizontal circle enables you to set the transit axis in the prime vertical; and as the telescope has a prism at the centre of the axis, to reflect the rays down the transit axis itself, the observer looks horizontally wherever the stars may be. It may be necessary to warn the unpractised observer that in this problem he only gets the *exact* latitude at once if the telescope passes through the zenith, or if the axis is truly horizontal. If the north end is high, for instance, 5″, the circle described by his instrument will pass 5″ to the south of the true zenith, and he will get by the formula given above an apparent co-latitude too great by 5″.

If the axis is very incorrectly placed with respect to the meridian, the co-latitude will be sensibly too small. Let the axis point to the east of the north; then the telescope describes a vertical circle passing through E′Z W, and Pz, which bisects S S′, will be the co-latitude which results from the formula.

If the true sidereal time be known with moderate accuracy, find how much the middle of the times of the star's transit over the supposed prime vertical, corrected for clock-error, differs from the time at which it actually passes the meridian, that is, from its right ascension. This difference is the ∠ Z P z, which is consequently known. Now from right-angled triangle P z z



$$\tan PZ.\ \cos.\ zPz = \tan Pz = \tan PS \times \cos. \tfrac{1}{2} \text{ elapsed time};$$

$$\text{or, } \tan \phi = \frac{\tan \delta \times \cos.\ ZPz}{\cos.\ \tfrac{1}{2} \text{ time elapsed}}.$$

It would be better to deduce the angle Z P z, which is the same for all stars, from a star which does not pass very near to the zenith, as the passage is more easily observed, but the length of time which elapses between the two passages of such a star is inconvenient. If the time is well known, one such passage will do.

If the observer has any means of determining the error in azimuth by a reference to known objects in the horizon, the correct latitude may be easily deduced from the approximate.

$$\text{Sin } Pz = \frac{\sin Pz}{\sin Pzz}, \text{ or } \cos \text{lat} = \frac{\text{cos. approximate latitude.}}{\text{cos. of azimuthal error.}}$$

Lastly, as almost all transits have vertical circles, which are or may be tolerably adjusted, the observer may measure the apparent zenith distances, z S and z S′, pretty nearly, and half the difference gives Zz.

Then cos P Z = cos Pz × cos Zz, or sin latitude = sin approximate latitude × cos of half difference in star's altitude east and west.

By reversing the instrument, any error of collimation or inequality of pivots will produce exactly a contrary effect on the latitude. Observations, therefore, of two stars on the same day in reversed positions, or of the same star on following days in reversed positions, will correct each other, and the mean will give the true latitude, that is, as nearly as the declination of the star is known. We have dwelt the longer and more minutely on this problem, because where great accuracy is required with but moderate means, it would seem that this is the best method of determining the latitude, and is, therefore, especially suited to coast surveying. It has been extensively used in the Russian navy, and by many travellers, German and Russian. There is one caution which the users of this method must not disregard, and that is, that the position of the instrument be so stable that no motion of theirs while observing can affect the horizontality of the axis. With this precaution, and such transits as are turned out of the best workshops here and abroad, a thirty-inch instrument will give, we conceive, the latitude within 1″ or 2″, without any particular skill on the part of the observer.

There is one word more to be said on the subject of pivots before concluding. By the mode in which they are turned and finished, they ought to be true cylinders, having their axes in the same right line; and so, no doubt, they are, very nearly, when the axis is strong and the pivots are turned in a good lathe, using a diamond for steel pivots. A little inequality of radius we have shown how to measure and correct for. But if the pivots are elliptical, the fault will not be shown by the level; and its effect will be to give the instrument a small variable error in azimuth, the period of which is 90°. There are several ways of trying whether the pivots have a correct form, but the error is so small as not to offer much hold to any direct method; and yet, if it does exist, no mass of observations will have any tendency to get rid of it. Reversion gives a chance of compensating the error in part; and we think the plan of rendering the object and eye end interchangeable is worth considering with a view to correcting such an error, at least in small instruments.

The right ascension of the standard fixed stars, as they are published by the principal observatories, do not in all instances agree as closely as might be expected from the mass of observations and the apparent accuracy of each. Whether this can be accounted for by supposing each catalogue to have a small variable error depending on the flexure of the axis of the instrument, or an error in the form of the pivots, is more than we can undertake to say; but it is a matter well worthy of investigation in the present state of practical astronomy.

We have deferred our account of the *Astronomical Observatory* until the principal instruments which form its furniture were described. We cannot attempt such a minute delineation as would suffice to guide any one who wished to erect such a building. It will be enough to state some of the properties which a well-contrived observatory should possess, and this may help an intelligent person to form a judgment after examining several of those which exist.

An observatory, as was well remarked by Römer, is nothing more than a covering for the instruments and a protection for the observer from the inclemencies of the weather. This should be steadily borne in mind by an architect who is called upon to furnish a plan for such a building, especially if he be limited in cost. The best situation is a gentle eminence which commands an uninterrupted view of the horizon, but which should not be abrupt or very high. The observatory at Cambridge is nearly perfect in this respect. The best foundation is undoubtedly rock; the foundation must be solid enough not to change rapidly. Absolute immoveability is not to be obtained. The supports of all instruments which are carefully watched show slow movements depending either on temperature or moisture, or some causes which are more obscure. No rule can be given as to the depth at which the foundations of the piers supporting the instruments should be laid, The deeper, broader, and more solid the better. The outer earth should not touch the base below the surface, and the outer walls should stand quite freely from it. The floor should be quite clear of a pier or its foundations. With these precautions the change of position in the instruments will be very slow, and when it is slow and uniform the effect is easily taken into account. In some of the earlier observatories, the instruments are placed high above the ground, and in several of the Italian and some Continental observatories they are at the summits of lofty towers. We need not say that any elevation beyond that which is required to command the horizon and keep the building dry and well ventilated is injurious. If distant meridian marks can be erected to the N. and S. it is of advantage, but this condition is not essential.

The instruments which are required for an observatory depend of course upon the class of observations which are to be pursued there. It has been too much the custom to build observatories nearly alike and to pursue exactly the same objects. We shall mention those instruments in order which may be considered important enough to give the name of observatory to their enveloping buildings.

The *transit* and its *clock*. These, on some scale or other, are required by almost every observer, as the time enters nearly into every observation, and a transit is the best instrument for getting it, and a good well-fixed clock is wanted for keeping the time when got. In principal observatories the transit is generally from five to ten feet focal length. We think the latter size unnecessarily large for the objects usually observed, and faint objects which require light, and consequently a telescope of large aperture, might be turned over to the large equatorial and micrometer. A 5-foot transit with an object-glass of the best quality will show everything that is usually observed, as well as the largest instrument, and is much more manageable. It can be levelled by one person with a hanging level and reversed by hand. The time can be got to the tenth of a second by a 45-inch or by a 30-inch transit, if they are of the *best* kind and well handled, so that these are sufficient for the most delicate determination of time. The larger transits are necessarily supported between two stone pillars, and we strongly recommend that the smaller transits should also be so mounted, when practicable, and on a sound and detached foundation. The clock is firmly fixed to its own insulated pier, or against a solid wall where there is not room or convenience for a separate pier. The best situation is with its face looking towards the observer when he is looking south, and so that the observing chair is not likely to strike it. The windows should be on the north side of the transit and circle rooms.

The *meridian circle,* which, in England at least, is always a mural circle, and, so far as we know, there has been hitherto no material improvement in the plan first followed by its inventor, Troughton. Perhaps if the circle were cast in one piece, the whole would be firmer. The standard size of the mural circle is six feet, but it has been made of eight, of five, and of four feet. The transit and circle require two observers, and consequently separate apartments, as the transit observer while counting the clock would be disturbed by any noise. Where two observers cannot be afforded, a *transit circle* may be made to answer both purposes, and such are used, in preference it would seem, in the German, Russian, and Italian observatories.

The transit, meridian circle, and clock are the instruments on which exact astronomy is founded, and they differ from other astronomical instruments in the observatory they require. This should be for each a square or oblong room, from 14 to 20 feet in its smallest direction, namely, north to south, and 10 or 14 feet high, with a slit of from 18 to 30 inches wide, cut in the direction of the meridian through the roof and side-walls, to about six inches below the height of the centre of the telescope. As this must be open during observation, it must be closed to exclude the weather by shutters easily removed. If the building is not very large, the vertical slits may be secured by a shutter in one or two pieces, and the top by one or more shutters turning on a hinge, pretty much like a box-lid, in a way that any good carpenter will understand. A specimen of what appears to us a very good fundamental observatory is the working part of that at Oxford, consisting of two square rooms like those described, separated by a small waiting-room between them and by an entrance. The slits in larger rooms may be closed by shutters which slide back and forwards by pulling the ropes attached to them. The shutters, where the opening is wide, are in halves, meeting in the middle. This is the Greenwich shutter: at Brussels the shutters are in one piece. At Cambridge the shutters are double, as at Greenwich, and the ropes connected with both sides are drawn simultaneously and either way by turning a winch. But whatever be the plan of the shutters, the opening must be wide enough to let the air within and without the building come to the same temperature very nearly. A telescope never performs well *optically* which peeps through a narrow slit, and the refraction must always be uncertain where the temperature of the air varies rapidly and irregularly.

The next instrument is the *equatorial,* which, when it is used for exact measurement depending upon the graduated circles, should scarcely have a larger telescope than one of five feet, with circles of from two to three feet diameter. Such an equatorial is intended at times to supply the place of the meridian instruments when the phenomenon observed is not visible on the meridian, and yet where the observations cannot be confined within the limits of the micrometer. The equatorial is necessarily an indifferent instrument, except used differentially; and in this case, the immoveability of the foundation is of less importance than the extent of the horizon. It is generally raised high enough to overlook the circle and transit rooms, and has a revolving roof with a slit on one side, which thus gives a command over the entire heavens. If an observer wishes for one instrument which will make good observations in any part of the heavens, he must confine himself to the *altitude* and *azimuth circle* under a revolving dome; but though everything may be done with this instrument, it must be admitted that it is with considerable expense of thought and calculation.

To be able to pursue some of the most interesting departments of modern astronomy, an observer must possess a telescope of large size, equatorially mounted, and carried by clock-work. This is especially designed for making all micrometrical observations, as those of double stars, diameters of planets, &c., and requires a graduated circle only for finding or identifying objects. Such an instrument is the superb telescope presented by the Duke of Northumberland to the Cambridge Observatory, which was mounted entirely on the plan of the astronomer royal. Instruments of this class are almost necessarily on the ground, and may be in an isolated building, if a better horizon can be thus commanded. It is not a simple thing to construct a rotatory roof of 25 or 30 feet diameter, light enough to be easily moved, and yet of sufficient strength, since it must necessarily have a slit on one side from top to bottom. The astronomer royal adopted at Cambridge a Chinese-looking form, namely, a flatter cone on the frustum of a sharper cone. There is a flattish channel on the top of the circular wall, in which half a dozen cannon-balls are laid at equal distances, and the roof rests on them, with another channel in its curb. This appears to be the cheapest, easiest, and most certain mode of getting a rotatory roof, but there is a good deal of rolling. The conical form is of much simpler construction than the spherical, and the shutters can be better applied to it; but in appearance the spherical form has greatly the advantage of any other form. For measuring objects which do not require a large field, the astronomer royal has applied a divided eye-piece, which answers very well. Both that and the usual micrometer are very limited as to the extent of angle they can measure; and where it is proposed to make most accurate measurements of angles, which may extend to 1°, the proper instrument is the *heliometer,* or equatorial with a divided object-glass. It is with this last-mentioned instrument that Bessel succeeded in establishing the existence of parallax, which had baffled astronomers ever since the existence of parallax was proposed as a test of the motion of the earth.

Lastly, if it is wished to cultivate that department of astronomy which we will call the *Herschelian,* an observatory must be furnished with gigantic reflectors, as it seems hopeless at present to expect that refractors can be made large enough to transmit sufficient light. These instruments however must almost of necessity be used in the open air.

A private astronomer would probably do most to advance the science by confining himself chiefly to extra-meridian observations, which may be taken up and left off at pleasure. A small transit for time, and as large an equatorial telescope as he can afford to set up, would be sufficient to employ his leisure very profitably.

An observatory is a very dull and uninteresting sight to any one who is not acquainted with the purposes to which it is applied; and we can scarcely conceive how Lalande could say, or others repeat after him, that a person would learn more of astronomy in one night in an observatory than in six months elsewhere. We should say there was no worse school; and that a person would learn astronomy far better from a celestial globe and a fine sky. It is probable, however, that Lalande supposed his learner to possess some elementary knowledge, and to be acquainted with the geometrical part of astronomy; in which case he would, no doubt, learn that in an observatory which is not to be learned or understood elsewhere.

There is no perfect model of an observatory, as respects the building, to which we can refer. Cambridge is, perhaps, the best, but on a larger scale than is necessary. We have already mentioned Oxford; Greenwich has nothing to recommend it as a building, but the goodness of the instruments, and the number and methodical arrangement of the observations and computations may be judged of from the printed Observations.

If an architect should have to construct a first-rate observatory, we should advise him, after learning what instruments are to be accommodated, to study each of these observatories, and arrange the rooms in the most convenient manner. The best appearance which the case admits of may be given afterwards, but he should not be very rigorous as to outside symmetry. It is scarcely possible to unite convenience as an observatory with a regular exterior, except at a considerable expense.

TRANSITS OF MERCURY AND VENUS. The inferior planets as they are called, whose orbits are within that of the earth, may sometimes appear to pass over the body of the sun, eclipsing, by their opacity, successive parts of the solar surface. The transits of Mercury and Venus are phenomena of this kind. They do not take place very often, as they can only be when the planet is in or very near to the node of its orbit, at the time when a line drawn through the sun's centre and that node passes through the earth. As the nodes of the planets alter their positions on the ecliptic very slowly, it will happen for many centuries together that these appearances can only take place at stated periods of the year in which they happen. A transit of Mercury is always either in May or November (according to the node of the orbit at which it takes place), and one of Venus in June or December. The first transit of Mercury which was observed took place in 1631, and of Venus in 1639, and the following are the dates of those which have occurred since, or will occur for a long time to come:—

Transits of Mercury.

Nov. 6, 1631.
Nov. 8, 1644.
Nov. 2, 1651.
May 3, 1661.
Nov. 4, 1664.
May 6, 1674.
Nov. 7, 1677.
Nov. 9, 1690.
Nov. 2, 1697.
May 5, 1707.
Nov. 6, 1710.
Nov. 9, 1723.
Nov. 10, 1736.
Nov. 2, 1740.
Nov. 4, 1743.
May 5, 1753.
Nov. 6, 1756.
Nov. 9, 1769.
Nov. 2, 1776.
Nov. 12, 1782.
May 3, 1786.
Nov. 5, 1789.
May 7, 1799.
Nov. 8, 1802.
Nov. 11, 1815.
Nov. 4, 1822.
May 5, 1832.
Nov. 7, 1835.
May 8, 1845.
Nov. 9, 1848.
Nov. 11, 1861.
Nov. 4, 1868.
May 6, 1878.
Nov. 7, 1881.
May 9, 1891.
Nov. 10, 1894.

Of these the transits yet to come in 1861, 1868, 1878, will be visible (weather permitting) in this country.

Transits of Venus.

Dec. 4, 1639.
June 5, 1761.
June 3, 1769.
Dec. 8, 1874.
Dec. 6, 1882.
June 7, 2004.
June 5, 2012.

Of these the transits of 1882 and 2004 may be visible in this country.

The use of these transits is threefold. First, they may be employed in correcting the tables of the planet in question; secondly, in computing the longitude of the place of observation; thirdly, in finding the actual distances of the planet and of the sun from the earth. The first of the uses is shared by the transits with many other kinds of observations, and as they occur so seldom, it is fortunate that in this respect they are by no means indispensable; and the same may be said of the second use. As to the third, the transits of Mercury, which occur with tolerable frequency, are comparatively useless, from the difficulty of the observation; but the transits of Venus are more available, and furnish our most precise mode of ascertaining the distance of the earth from the sun.

It cannot be shown *precisely* to any but a mathematician, how it is that the observation of a transit of Venus at several different places on the earth's surface is made to answer the above purpose. The phenomenon itself obviously resembles an eclipse of the sun, as distinguished from one of the moon; and is affected in its progress by the rotation of the earth. If a spectator were placed at the earth's centre, he would see Venus pass over a certain line on the sun's disc, traced out by a moving line the end of which is in his own eye, and which passes through the centre of Venus. Whenever this line passes through the sun's surface, Venus will appear to be projected on that surface as a dark spot. At the same time a spectator on the surface of the earth will refer the spot to a different point of the sun's surface, and the thing to be noted is, that the difference of the lines which Venus appears to pass over on the sun's surface depends jointly on the spectator's place and the positions of Venus and the sun. The formula by which the time of transit is connected with these two things—the spectator's place, and the position of Venus and the sun—points out that the difference of the apparent beginnings and endings of the transit at different places on the earth's surface depends entirely on the difference of the distances of the sun and Venus from the earth (as is sufficiently evident without the formula; for if the planet were at the same distance from us as the sun, that is, if it really passed over the body of the sun, the phenomena would not be sensibly different at any two parts of the earth). The distances of the sun and planet enter into the formulæ by means of their parallaxes [Parallax]; and if the difference of the parallaxes is once known, the parallaxes themselves are known, for the proportion of the distances of the earth and Venus from the sun is sufficiently well ascertained from Kepler's laws. At a place of known longitude, if only the ingress or egress of the planet be observed, either of the two, and if the phenomenon can be calculated as it would be seen from the centre of the earth, then the difference of the parallaxes can be found; but this supposes, first, that the longitude of the place is very well known; secondly, that the errors of the tables of the sun and Venus are insensibly small. If both the beginning and ending of the transit can be observed at one place, it is no longer of any consequence that the longitude of the place should be so accurately known; an approximate determination of it will be sufficient. Still the errors of the planetary tables remain. But if both beginning and ending of the transit can be observed at two different places (and the greater their difference of longitude the better), then the differences of the parallaxes can be computed from the two observed durations of the transit, independently both of the longitudes of the places and of the planetary tables, that is, so as not to be rendered sensibly inaccurate by any moderate inaccuracy in either. The fact is, that when the transit is observed at one place only, the formulæ suppose it to be known at some other, either the centre of the earth, or Greenwich or some other observatory. When the transit is observed at two places, the second observation is inserted instead of the computed substitute for observation. This explains why it was that expeditions were sent by different governments to different parts of the globe to observe the transits of 1761 and 1769. If the transit should be seen both at its beginning and ending at six different places, every pair of them (and there are 15 pairs) would give a determination of the difference of parallaxes, and the mean of all the results would be entitled to a high degree of confidence.

The first transit of Mercury that was ever observed was seen by Gassendi, November 6, 1631; the first transit of Venus by Horrocks, December 4, 1639. Halley pointed out the use of such transits, and preparation was made to observe that of 1761. Legentil was sent to India, Chappe to Tobolsk, and Pingré to the island of Rodriguez, by the French government; Maskelyne went to St. Helena, and Mason to the Cape of Good Hope (he intended, but was prevented, to go on to Sumatra). The weather hindered or injured most of the observations; the most fortunate was that of Mason, who made the sun's parallax eight seconds and a half. The transit of 1769 was still better attended to. The complete duration of the transit was observed at Cape Wardhus, Kola, Cajaneburg, O-taiti, Fort Prince of Wales on the north-west coast of Hudson's Bay, St. Joseph, and Santa Anna in California. The ingress of the planet was seen at almost all the observatories of Europe; the egress at Petersburg, Yakutsk, Manilla, Batavia, Pekin, Gurief, Orska, and Orenburg. The value of the parallax was variously deduced, different astronomers preferring different values, from 8″·5 to 8″·8: Laplace used 8″·66; M. Encke deduced 8″·5776 from all the observations. De Ferrer ('Mém. Astron. Soc.,' vol. v., p. 256), from a re-examination of the whole observations, deduces 8″·58, and thinks this cannot be wrong by so much as $\frac{1}{100}$ths of a second.

Most of the observers who saw the ingress of the planet unite in stating that after the planet had entered on the sun, it continued for a short time to appear as if it were joined to the limb or border of the sun by a dark protuberance or ligament (some call it a thread). This phenomenon appears to be of the same sort as that noticed in Sun with respect to the annular eclipse. A full account of what was seen with respect to Venus will be found in Mr. Baily's paper there referred to. ('Mém. Astron. Soc.,' vol. x., p. 1.)

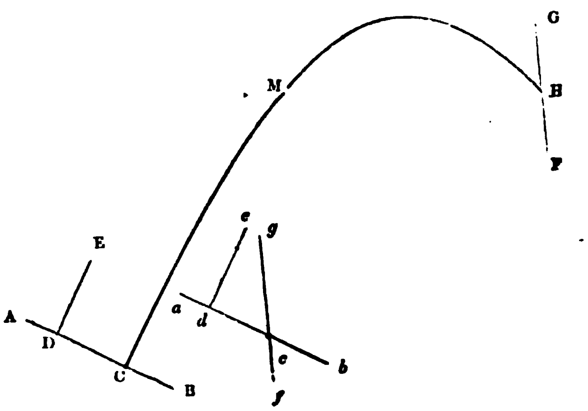
TRANSLATION. This word is used in mechanics, as distinguished from Rotation, in the following manner:—A body has motion of translation when all its points move in parallel straight lines; when, in fact, all its points have the same motion. If all have not the same motion, there is either simple rotation, that is, about one permanent axis; or rotation about a varying axis; or else a compound of translation and rotation.

The point which is called the centre of gravity of a system, and which is of no small importance in the theory of equilibrium, has yet more in that of motion. The motion of any free system is compounded of the translation of its centre of gravity, and the rotation about an axis (whether always in one direction or not) passing through its centre of gravity. Now whatever the forces may be by which such a system is either set in motion, or acted on while in motion, the translation of its centre of gravity may always be made a distinct problem from the rotation about its centre of gravity, by the following simple rules:—

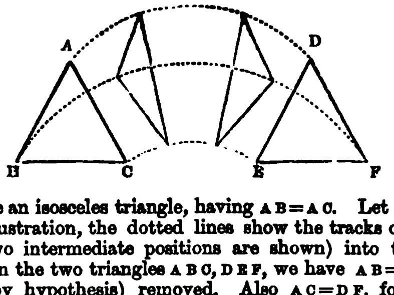
1. The centre of gravity moves just as it would do if the whole system were there collected, and all the forces were there applied.

2. The rotation of a system about its centre of gravity is no other than what it would be if that centre were made a fixed point, and all the forces applied in their proper places.

Suppose, for instance, a bar A B, whose centre of gravity is at C, is sent spinning into void space by a certain blow in the direction D E, communicated at D. Let there be another similar bar *ab*, whose centre of gravity *c* moves on a fixed pivot without friction, and which, being parallel to A B, is struck at the same instant with a similar blow in the direction *de*. To find the position of the bar at the end of any given time, say three seconds, is a twofold problem, as follows:—First suppose all the mass of the bar concentrated at C, and let the blow be struck, with the same force and direction, at the point C. This point C will then describe a certain parabola CMH; say that in three seconds it is at H. Next turn to the bar which moves on a fixed pivot, and let *fg* be its position in three seconds. Draw FG, a position of the bar parallel to *fg*, H being its centre of gravity, and FG will be the real position of the bar at the end of the given time, three seconds; and similarly for any other given time.



Thus much of translation, mechanically considered: we now speak of the wider use which the word has, or might have, in geometry; at any rate we have the thing to consider, and perhaps *transference* might be preferable to translation, as applied to the motion of a figure from one part of space to another. The conception of the possibility of figures differing only in position, and composed of perfectly equal and similar parts of space, similarly bounded, is one which is demanded of the beginner in geometry. Euclid requires this when he speaks of equal figures; and his test of equality, namely, the possibility of creating a perfect coincidence, requires the notion of one figure being transferred in any requisite manner, whether by what is called in mechanics translation, or by rotation, or both. It must be a sort of copy, or facsimile, of one part of space which is thus moved into and made to occupy another: for it is impossible to imagine *space removed*, or any part of *space* made to change place. And this copy, or whatever it may be, must have rigidity, that it may not change form by the way: it must be rigid in our thoughts, at least. We are thus required to imagine space endowed with some of the essential qualities of matter, before we can prove the fourth proposition of Euclid's first book: there must be the consistence of matter without its impenetrability, but whether it require force and time to change place, or not, is of no consequence. Even a plane figure must be a sort of rigid consistence with two sides to it, for it is necessary to imagine it turned round, so as to present a different face to the spectator. In the fifth proposition of the first book, the very first step is the application of the fourth proposition to prove the equality of two triangles. Now the fourth proposition requires one triangle to be placed upon the other, which cannot be done in the figure of the fifth, unless one of the triangles be turned round, so as to show the other front to the spectator. If Euclid meant, by giving the triangle two handles, to make it easier to turn, he has been unfortunate, for the proposition has acquired the name of the *ass's bridge*, probably as being that which stops a dull reader. The following proof is as correct as that of Euclid, and it is not much to say that those who do not understand it will not understand the one he gave.



Let ABC be an isosceles triangle, having AB = AC. Let it be turned round (for illustration, the dotted lines show the tracks of the three points, and two intermediate positions are shown) into the position DEF. Then in the two triangles ABC, DEF, we have AB = DE, for DE is AC (= AB by hypothesis) removed. Also AC = DF, for a similar reason. And the angle BAC = the angle EDF, the second being only the removal of the first. Hence we have AB = DE, AC = DF, and $\angle BAC = \angle EDF$, and now by the fourth proposition it follows that $\angle ABC = \angle DEF$. But $\angle DEF$ is only another position of $\angle ACB$; whence $\angle ABC = \angle ACB$, which was to be shown. If preferred, the triangle ABC might be turned round upon itself, and the reasoning of the fourth proposition applied at once.

It is not to be supposed that Euclid did not see the preceding: but he is a writer who very rarely goes out of the most obvious path without some cogent reason connected with his system. The proof given above would not serve to demonstrate the equality of the external angles without the previous introduction of the properties of adjacent angles; and it happens that the knowledge of the equality of the external angles is immediately wanted.

TRANSLATION. [VERSION.]

TRANSMUTATION OF METALS. [ALCHEMY.]

TRANSOM. [MULLION.]

TRANSPARENCY is that quality of certain substances or media by which rays of light are allowed to pass freely through them. It is doubtful whether any substance exists which is perfectly transparent; for even water and air stop more or less of the light passing through them when the length of its path is very great. It is, however, exceedingly difficult in such cases to say whether the observed stoppage be due to the pure substance, or to foreign bodies present in proportions otherwise perhaps inappreciable. On the other hand we have reason to believe that all bodies possess the property of transparency in a certain degree. Thus many metals have been obtained by mechanical or chemical means in such a state of thinness as to transmit a certain amount of light; for example, gold, which in the state of gold-leaf transmits a greenish light.

There are two distinct obstacles to transparency, one a defect of homogeneity, whereby a portion of the light in its onward progress is continually reflected in another direction, at the surface of separation of adjacent portions of the body having different refractive powers; the other the power which a very great number of substances possess of *absorbing* light. [ABSORPTION OF LIGHT.] A good example of the former is afforded by snow, which in sufficient thickness prevents the transmission of light, but simply in consequence of its reflecting the light backwards at the various surfaces of the icy crystals; and accordingly snow is brilliantly white by reflection, whereas the single reflection from a sheet of water or ice is comparatively feeble. Other examples are afforded by a mixture of water and oil, or water and bisulphide of carbon, shaken up together; or better still, an alcoholic solution of bisulphide of carbon precipitated by the addition of water. In these cases mixtures are obtained which, from the multiplied reflections, have a milky appearance, and in sufficient thickness stop transmitted light, though the mixed fluids (bisulphide of carbon and watery alcohol in the last example) are separately transparent. The transparency of white paper is greatly increased by oiling the paper, the reason of which is that the quantity of light reflected at the common surface of the fibres and oil, which do not very greatly differ in refractive power, is very much less than that reflected at the common surface of the fibres and air. The mineral hydrophane derives its name from becoming more transparent after being placed in water, which is in consequence of its imbibing water in the pores with which it is filled.

Examples of the second obstacle to transparency are sufficiently familiar, as may be gathered from the article on ABSORPTION. Thus the common blue glass cuts off a large quantity of the light incident upon it, and when in tolerable thickness may for most purposes be regarded as opaque. Most commonly both obstacles to transparency exist together, as in the case of wood, cork, brick, dyed cloths, &c.

That homogeneity should be one requisite for transparency, follows from the existence of reflection at the common surface of media of unequal refractive power; and therefore in considering the cause of transparency it will be sufficient to confine our attention to homogeneous media. In such media transparency is to be contrasted with the power of absorbing light; the former in the absence of the latter. The speculations at one time entertained respecting the cause of absorption on the supposition that light consists in particles darted forth by the luminous body can now only be matter of history; we shall confine ourselves to a consideration of the probable cause of absorption, on the supposition that light consists in the tremors of an elastic medium.

In the case of gaseous media especially, the rate of absorption of light passing through them changes, in many instances, in a very remarkable manner with the refrangibility of the light. Hence the spectrum of white light subjected to prismatic absorption on the part of such media, presents fluctuations of intensity, simulating more or less completely effects due to interference. Accordingly attempts have been made to refer absorption to ordinary interference. But such explanations labour under one fatal defect; they suppose the annihilation of *vis viva*. The effect of ordinary interference is not to *destroy* light, but merely to alter the distribution of illumination. Thus, when the light of a rather distant candle is reflected from a thin plate of mica bent into a cylindrical form, and the linear image of the flame is analysed by a prism, it is true that dark bands are seen which remind one of the bands produced by the absorption of light by the vapour of iodine, and were applied by the Baron von Wrede to the explanation of the latter phenomenon, and of absorption in general. (Poggendorff's 'Annalen,' vol. xxxiii. (1834), p. 353, and Taylor's 'Scientific Memoirs,' vol. i., p. 477.) But there is this difference between the two cases, that in the experiment with mica, the light which is defective in the reflected beam is found in excess in the transmitted beam, which would yield a spectrum having bands complementary to those of the former; whereas in the case of absorption the missing light actually disappears *as such*. It is not however annihilated; an effect is produced on the medium, whether it be that the temperature is raised, or that chemical changes are produced, or that the medium is made to emit light of a different kind, as in the phenomena of phosphorescence and fluorescence. [FLUORESCENCE.] These phenomena, and especially perhaps the last, indicate that the molecules of the medium are thrown into a state of agitation; and thus we are led to suppose that the undulations of the luminiferous ether are spent in producing agitations among the ultimate molecules of the absorbing body, the consideration of which therefore must form an *essential* part of a complete explanation of absorption. That the period of the incident undulations should play such an important part in the phenomena, may be illustrated to a certain extent by considering the effect of a series of slight pushes, periodically applied to a body capable of swinging as a pendulum, which will throw it into a state of considerable vibration, provided the period of the pushes nearly agrees with that of the natural vibrations of the body. If the cause of absorption be that just explained, we must attribute transparency to the existence of such a constitution in the body, that the ether, or a portion of it at least, can in its undulations glide freely among the molecules of the body, without throwing them into a state of agitation.

TRANSPIRATION, a term applied by Mr. Graham to a peculiar and fundamental property of the gaseous form of matter in passing through capillary tubes. It differs from EFFUSION by which gases pass through a small aperture about $\frac{1}{500}$th of an inch in diameter, into a vacuum; but some of the results of transpiration correspond with the flow of liquids through capillary tubes referred to under DIFFUSION.

The results obtained by Dr. Poiseuille, and confirmed by Regnault, were obtained by sending a liquid under examination through a capillary tube under the influence of condensed air of known pressure. For a minute account of these experiments we must refer to the 'Annales de Chimie,' 3e serie, xxi.; an abstract of them is also given in Professor Miller's 'Chemical Physics,' where the apparatus is also figured. Among the general results obtained, it appears that the rate of efflux of the liquid when the tube exceeds a certain length (which is greater as the diameter increases) increases directly as the pressure, so that by doubling the pressure, the amount of liquid discharged is double, the times being equal. With tubes of equal diameter the quantities discharged in equal times are inversely as the length of the tube, so that a tube two inches long discharging 100 grains of liquid in five minutes, a similar tube four inches long would discharge only 50 grains in the same time. In tubes of equal lengths but of different diameters, the flow is as the fourth power of the diameters, so that the flow from a tube $\frac{1}{50}$th of an inch in diameter would be 16 times as great as from a tube $\frac{1}{100}$th of an inch in diameter, or as $1^4 : 2^4$. The material of the tube does not appear to influence the result; but the nature of the liquid does so greatly. In most cases the flow of saline solutions was found to be slower than that of distilled water: the alkalies produced this effect. Certain substances appeared to exert no influence, such as nitrate of silver, corrosive sublimate, iodide of sodium, iodide of iron, nitric, hydriodic, bromic, and hydro-bromic acids. The presence of some other substances increased the rapidity of the flow, such as hydro-sulphuric acid and hydro-cyanic acid; the nitrates of potash and ammonia, the chlorides of potassium and ammonium; the iodide, bromide, and cyanide of potassium. A slight increase in temperature generally augments the flow; water at 113° escaping $2\frac{1}{4}$ times quicker through the same tube than it did at 41°. But it is remarkable that concentrated solutions of iodide of potassium above 140° Fahr., and of nitrate of potash above 104° flow more slowly than distilled water. In general, however, the solutions contained only 1 per cent. of the substances; and they were exposed to a pressure equal to that of a column of water 1 mètre (39·37 inches) high, at the temperature of 52°·16, and escaped through a tube 64 millimetres (2·519 inches) in length, and 0·24946 millimetres (0·0108 inch, in diameter. No connection has been traced between the rate of efflux of the liquid and its density, capillarity or fluidity. The dilution of alcohol retards its efflux, up to a certain point, beyond which it increases it, the minimum efflux corresponding with that mixture of alcohol and water which is attended with the maximum contraction. The solubility of a substance in water exerts only a secondary influence on the efflux. Dr. Poiseuille has shown that various solutions introduced into the blood of a living animal apparently produce effects of acceleration or retardation on the capillary circulation corresponding with those noticed with the same liquids in glass capillary tubes.

Substituting gases for liquids, it appears that the rate of efflux, or the velocity of transpiration for each gas, is independent of its rate of diffusion. In Graham's experiments on this subject, ('Phil. Trans.' 1846 and 1849) the gas was contained in a graduated jar, standing over water, and suspended so that the water on the inside should be kept on the same level as that on the outside. On allowing the jar to sink, the gas was expelled by a flexible tube into a bent tube containing chloride of calcium, and being thus dried, it passed through a long capillary tube, and thus entered the exhausted receiver of an air pump, which was either kept exhausted, or the amount of exhaustion was noted by means of the gauge, the quantity of gas that entered the receiver in a given time being carefully noted.

By employing a certain length of tube increasing with the diameter, not the same for all gases, it appears that the rate of transpiration increases directly as the pressure, so that equal volumes of air at different densities require times inversely proportioned to the densities:—thus a pint of air double the density of the atmosphere will pass through the capillary tube into vacuum in half the time required for a pint of air of ordinary density. With tubes of equal bore the volume transpired in equal times is inversely as the length of the tube; thus, if 30 cubic inches of gas were transpired through a tube 10 feet long in 5 minutes, a similar tube 20 feet long would only allow the passage of 15 cubic inches in the same time. It was also found that the transpiration of equal volumes becomes slower as the temperature rises. Uniform results were also obtained, whether the tubes were of copper or of glass, or a porous mass of stucco were employed. Transpiration was found to vary with the chemical nature of the gases. The velocities of transpiration of different gases bore a constant relation to each other, independently of their densities, and it was thought probable that the rate of transpiration is the resultant of a kind of elasticity depending on the absolute quantity of heat, latent as well as sensible, which different gases contain under the same volume, so that transpiration seems to be intimately connected with the specific heat of gases.

Oxygen has apparently the slowest rate of transpiration, and is taken as the unit in the following table. It is found that a mixture of equal volumes of two gases does not always give the mean transpirability. Thus the time for the transpiration of hydrogen is much prolonged by admixture of oxygen, the rate being 0·9008 instead of the mean 0·72.

Gases.	Times for Transpiration of equal volumes.	Velocity of Transpiration.
Oxygen	1·0000	1·0000
Air	0·9030	1·1074
Nitrogen	0·8768	1·141
Binoxide of nitrogen	0·8764	1·141
Carbonic oxide	0·8737	1·144
Protoxide of nitrogen	0·7493	1·334
Hydrochloric acid	0·7363	1·361
Carbonic acid	0·7300	1·369
Chlorine	0·6664	1·500
Sulphurous acid	0·6500	1·538
Sulphuretted hydrogen	0·6195	1·614
Light carburetted hydrogen	0·5510	1·815
Ammonia	0·5115	1·935
Cyanogen	0·5060	1·976
Olefiant gas	0·5051	1·980
Hydrogen	0·4370	2·288
Vapours.		
Bromine, about	1·0000	
Sulphuric acid, anhydrous	1·0000	
Bisulphide of carbon	0·6195	
Chloride of methyl	0·5475	
Chloride of ethyl	0·4988	
Oxide of methyl	0·4826	
Hydrocyanic acid	0·4600	
Ether	0·4400	

In these experiments capillary glass tubes, varying from 20 feet to 2 inches in length, gave similar results, where a sufficient resistance was offered to the passage of the gas. The effusion of gases, or the discharge by an aperture in a thin plate, is dependent in all gases upon a constant function of their specific gravity; but the discharge of the same gases from tubes has no uniform relation to the density of the gases. Both hydrogen and carbonic acid, for example, pass more quickly through a tube than oxygen, although the one is lighter and the other heavier than that gas.

One of the capillary tubes used by Graham was as much as 22 feet in length; it was made up of several portions of capillary tube as nearly equal in bore as could be judged of by the eye, cemented together by the blow-pipe so as to form a continuous length, but bent up into coils for the convenience of using. Its extremities were connected with block-tin tubes, proceeding from the drying-tube and air-pump jar by means of thick caoutchouc adopters. This long capillary tube allowed one cubic inch of air to pass into a vacuum in 15·64 seconds; two inches of the tube held 2·65 grains of mercury, which gives a diameter of 0·0222 inch, or $\frac{1}{45}$th of an inch.

It was found possible to form a capillary tube of copper of less diameter than one of glass, by the following means:—a cylindrical hole was first drilled in the axis of a solid copper rod, four or five inches long, which rod was then extended by passing it through a wire draw-plate. An iron wire, or triplet, was placed within the copper tube, and drawn through the plate at the same time, in order to keep the surface of the copper tube smooth and uniform. It was found necessary to pull out the iron wire every time the copper was drawn, to prevent its becoming fixed. The iron wire was then extended separately, and again introduced into the copper tube, and the operation of drawing out was repeated. In this way the copper tube was extended 11 feet 8 inches, and it remained perfectly sound and air-tight. One cubic inch of air passed through it into a vacuum in 22·12 seconds. Its diameter was thus found:—Of the iron wire on which the copper was last drawn, 92·7 inches weighed 18·30 grains, or one inch weighed 0·1974 grains. Taking the specific gravity of iron at 7·7, this gives the diameter of the copper tube 0·0114 inch, or $\frac{1}{88}$th of an inch. In using this tube for transpiration experiments, it was coiled up into circles about 10 inches in diameter.

Mr. Graham's experiments, which are exceedingly numerous, are very neat and precise in their results: the experiments of Dr. Poiseuille have also an equal constancy and precision of result in the passage of liquids through capillary tubes which is quite remarkable. To take, for example, a few of Mr. Graham's results: the transpiration velocity of hydrogen is exactly double that of nitrogen, although the relation in density is as 1 : 14. The transpiration of carbonic oxide, like the sp. gr., is also identical with that of nitrogen. The transpiration velocity of oxygen is related to that of nitrogen in the inverse ratio of the densities of these gases, that is, as 14 : 16. In equal times, and with equal weights (not equal volumes) of these two gases, the more heavy gas was more slowly transpired in proportion to its greater density. Mixtures of oxygen and nitrogen have the mean velocity of these two gases, and hence the time of air is also found to be proportional to its density when compared to the time of oxygen. Indeed, the velocity of different gases through capillary tubes, bears a constant relation to each other. The constancy of these relations, or of the transpiration times, has been observed for several of the gases for tube resistances, varying in amount from 1 to 1000. These relations are more simple in their expression than the densities of the gases. It is, indeed, very remarkable to find the velocity of hydrogen to be exactly double that of nitrogen and carbonic oxide; the velocity of nitrogen and oxygen to be inversely as the specific gravity of these gases; the velocity of binoxide of nitrogen to be the same as nitrogen and carbonic oxide; the velocity of carbonic acid and nitrous oxide to be equal and directly proportional to their specific gravities when compared with oxygen. In like manner, it is found that the velocity of proto-carburetted hydrogen is 0·8, hydrogen being = 1, the velocity of chlorine is 1½ that of oxygen, of bromine vapour and sulphuric acid vapour the same as oxygen, while that of ether vapour is the same as hydrogen. Olefiant gas, ammonia, and cyanogen are equal, or nearly equal, in velocity which approaches closely to double that of oxygen. Hydrosulphuric acid gas and the vapour of bi-sulphide of carbon have an equal transpiration time. The compounds of methyl have a less velocity than the corresponding compounds of ethyl, but are connected by a certain constant relation.

Among the general results obtained by Mr. Graham are the following:—2. That the resistance of capillary tubes of uniform bore to the passage of any gas is directly proportional to the length of the tube. 3. That the velocity of the passage of equal volumes of air of the same temperature, but of different densities or elasticities, is directly proportional. 4. That rarefaction by heat has a precisely equal effect in diminishing the velocity of the transpiration of equal volumes of air, as the loss of density and elasticity by diminished pressure has. 5. That a greater resistance in the capillary tube is required to bring out the third result, or law of densities, than is apparently necessary for the first or second result, and a resistance still further increased, and the highest of all, to bring out the fourth result, or the law of temperatures. 6. That transpiration is promoted by density, whether due to compression, to cold, or to the addition of an element in combination, as the velocity of oxygen is increased by combining with carbon, without change of volume in carbonic acid.

With respect to the influence of transpiration on the distribution of coal-gas by means of pipes, the results are similar with truly elastic gases whether the tubes be capillary or many inches in diameter, provided the length of the tube be not less than 4000 times its diameter. The small propulsive pressure applied to coal-gas is favourable to transpiration as well as the great length of the mains. The velocity of coal-gas should be 1·575, air being 1 under the same pressure. With a constant propulsive force in the gasometer, the flow of gas should increase in volume with a rise of the barometer or with a fall in temperature directly in proportion to the increase of its density from either of these causes.

TRANSPORTATION (*trans* and *porto*), removal, banishment to some fixed place. Transportation, as a punishment for crime in England, having been practically abolished, it is only in its historical point of view that it will be here considered. Under CRIMES AND PUNISHMENTS; LAW, CRIMINAL; and PENAL SERVITUDE, will be found the present state of the law with regard to the punishment of crime, and the nature of the system of imprisonment.

The statute of 39 Elizabeth, c. 4, for the banishment of dangerous rogues and vagabonds, was virtually converted by James I. into an act for transportation to America by a letter to the treasurer and council of the colony of Virginia, in the year 1619, commanding them "to send a hundred dissolute persons to Virginia, which the knight-marshal would deliver to them for that purpose." Transportation is not distinctly mentioned in any English statute prior to the stat. 18 Car. II., c. 3, which gives a power to the judges at their discretion either to execute or transport to America for life the moss-troopers of Cumberland and Northumberland. Until after the passing of the stat. 4 Geo. I., c. 2, continued by stat. 6 Geo. I., c. 23, this mode of punishment was not brought into common operation. By these statutes the courts were allowed a discretionary power to order felons who were by law entitled to benefit of clergy to be transported to the American plantations. Transportation to America under the statutes of George I. lasted from 1718 till the commencement of the War of Independence in 1775.

A plan for the establishment of penitentiaries, which was strongly recommended by Judge Blackstone, Mr. Eden (afterwards Lord Auckland), and Mr. Howard, was taken into consideration by parliament, and the act 19 Geo. III., c. 74, for the erection of penitentiaries, passed. The government failed, however, to adopt the necessary measures for its execution; and transportation was resumed by an act passed in the 24th year of George III., which empowered his majesty in council to appoint to what place beyond the seas, either within or without his majesty's dominions, offenders should be transported; and by two orders in council, dated December 6th, 1786, the eastern coast of Australia and the adjacent islands were fixed upon. In the month of May, 1787, the first band of convicts left England, which in the succeeding year founded the colony of New South Wales.

By statute 5 Geo. IV., c. 84 (amended by the 11 Geo. IV., and 1 Will. IV., c. 39) the crown was empowered to appoint places beyond the seas to which persons under sentence or order of transportation or banishment should be conveyed, the governor of the colony, or his assignee, having the property in the service of the convicts. The crown was also empowered to appoint places of confinement at home, either on land or on board vessels in the Thames, or other rivers or harbours, for the removal and confinement of male offenders (extended by the stat. 16 & 17 Vict. to females) under sentence of death, but reprieved or respited, or under sentence of transportation, there to remain under order of the Secretary of State until entitled to their liberty, or removed, or otherwise dealt with. The capital punishment for offenders found unduly at large before the expiration of their sentence, was still retained, but was subsequently abolished by the stat. 4 & 5 Will. IV. c. 67, which substituted transportation for life, with previous imprisonment not exceeding four years.

New South Wales, Van Diemen's Land, and Norfolk Island became, under these statutes and an earlier statute of George III., the principal receptacles for convicts. The power of the colonial governors to remit sentences was next restrained by the stat. 2 & 3 Will. IV., c. 62, they being only empowered to pardon or remit labour after the convicts had undergone a certain portion of their sentence; but this statute was repealed by the 6 & 7 Vict. c. 7, which provides that, instead of governors of colonies remitting either absolutely or conditionally the period of transportation, the governors shall recommend felons to government at home for pardon, and they are to be pardoned according to the instructions received thereupon, such pardons having the same effect as a pardon under the great seal.

Although, as already stated, the property in the services of convicts was vested in the colonial governor, a practice prevailed in those places to which offenders were transported, of granting them in certain cases permission to employ themselves for their own benefit. These permissions were usually called "tickets of leave." By the stat. 6 & 7 Vict. c. 7, the legislature, thinking it just that such convicts should be protected in their persons and in the possession of such property as they might acquire by their industry, empowered them to hold personal property, and to maintain actions in respect thereof while their tickets remained unrevoked.

The reception of convicts having, however, become distasteful to the colonies, the stat. 10 & 11 Vict. c. 67, was passed, permitting offenders under sentence of transportation to be removed to any prison or penitentiary in Great Britain; directors of the principal convict prisons being appointed afterwards under the stat. 13 & 14 Vict. c. 39. The difficulty attending the reception by the colonies of transported convicts having increased, the stat. 16 & 17 Vict. c. 99, next abolished the punishment of transportation for any term less than fourteen years, and substituted penal servitude, giving the courts power in all cases to award that punishment in lieu of transportation.

Finally, the stat. 20 & 21 Vict. c. 3, abolished transportation altogether as a punishment, substituting PENAL SERVITUDE; but convicts under sentence of penal servitude may still be sent beyond seas by order of the Secretary of State.

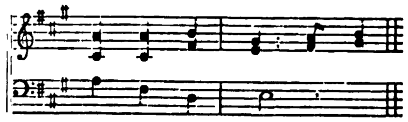
Transportation was of great value to our early colonists, as it supplied what was so essential to their well-being—cheap labour. From Australia it was subsequently extended to the settlements of the Cape of Good Hope, to Bermuda, and Gibraltar, but the last two were (and are) more of the nature of places of penal imprisonment abroad; and with respect to Bermuda, it has been recently (1861) announced by the Secretary of the Colonies that the government have adopted measures for diminishing the number of convicts at Bermuda, with a view to the early abolishing of transportation to that colony.

All convicts sent to Bermuda or Gibraltar are employed by the government on public works in the dockyards and fortifications. The system of punishment pursued is essentially different from that which has been in force in the Australian penal colonies. The convicts sent to Bermuda are kept apart from the free population; they are shut up in hulks by night, and are worked in gangs by day under the superintendence of free overseers. A small amount of wages is paid to them for their labour, a portion of which they are allowed to spend, and the remainder forms a fund, which they receive on becoming free. At the expiration of their sentences they do not remain in Bermuda, but are sent back at the expense of the government of this country.

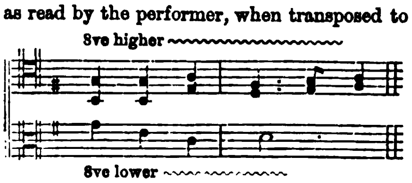
Mr. Bentham, Dr. Whately, the present archbishop of Dublin, and other writers on the theory of punishment, have condemned the general principle of transportation; and comparatively little has been urged in opposition to their arguments. Mr. Bentham's objections will be found in a chapter on Transportation, in his 'Theory of Punishments;' the archbishop of Dublin's, in his two 'Letters to Earl Grey.' These arguments, but still more the resolutions of the colonies not to receive any more convicts, led to the abandonment of the system. The colonists were no doubt right in refusing to let their society continue to be the receptacle of the crime and profligacy of the parent state; but it is not so clear from doubt that in an early stage of settlement the system of transportation may not be adopted with advantage; indeed the remarkable prosperity of Australia, if not its very existence as a settlement, is owing to this system. Where the population is small, and labour scarce, the criminal is removed from much temptation, and placed in the very best position for retrieving his character; while the settler has the benefit of cheap and constant labour. The expense, however, to the parent state is large; it was estimated that in transporting to Australia each convict cost the state 82*l*.

TRANSPOSITION, the name given in Algebra to the process of removing a term from one side of an equation to another, changing its sign. Thus, if $a=b+c$, by transposition, $a-c=b$. On this we have only to remark, that in this instance the rule is not much of an abbreviation. If we say "transpose *c*," instead of "take *c* from both sides," so little is gained, that it may be doubted whether it would not be better to follow the Continental writers in the use of the latter form of expression: a process which would have the advantage of being a perpetual appeal to reason instead of rule.

TRANSPOSITION, in Music, is a change of the original key to one higher or lower. This is generally performed at a moment's notice by the accompanist to suit the convenience of the singer. To the latter, transposition is not attended with any difficulty: the change is little more than imaginary, except so far as relates to the compass of the voice. To the accompanist it is far otherwise; unless playing from memory, he must assign to all the notes as regards their pitch or their situations on his instrument, names wholly different from those in the copy placed before him. To accomplish this he has to *suppose* a change of clef, or clefs, and thus give new designations to all the lines and spaces. For instance—and without going into the extreme case of transposing from a score—a pianoforte player is required to transpose an air a whole tone lower,—from A to G. For this purpose he must assume a change in both clefs, the treble into the tenor, and each note to be played an octave higher than it is written; the bass into the alto, and each note to be played an octave lower than it is written. Example in A.



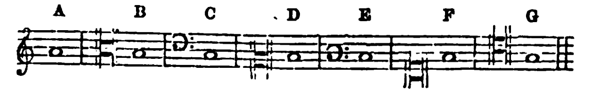
The same as read by the performer, when transposed to G:—



The difficulty attending this process is so great, that no amateur, and few discreet musicians, unless professed accompanists, or well acquainted with the composition to be transposed, will undertake the task; for to perform it in an artist-like manner, at first sight, requires a degree of practical skill only to be gained at the expense of much time that might be employed to far greater advantage in studying those higher branches of the art in which the most experienced will always find something to learn. Our remarks, it will be understood, relate to performers on the pianoforte and organ. To those who read from a single staff, and play single notes only, as violinists, flutists, &c., the task of transposing is comparatively easy.

To meet all the demands of transposition, a familiar knowledge of no less than seven clefs is necessary, and two of these—the mezzo-soprano, and baritone, or bass clef on the 3rd line [Clef]—may be said to have become obsolete.

The annexed table will exemplify the use of clefs in transposition. It shows how to transpose a given key-note—A for instance—into any other note of the scale, and, consequently, how to transpose the whole of any composition. It is hardly necessary to add, that the semitonic scale, as concerns line and space, is governed by the diatonic; that A♯, A♭, &c., have the same places in the staff as the natural notes represented by the same letters.



TRANSUBSTANTIATION. [Sacraments].

TRANSVERSAL, a name lately given to a line which is drawn across several others, so as to cut them all. The word is used in this sense in the writings of Carnot, Poncelet, Chasles, &c.

Let there be a triangle ABC (the reader may easily draw the figures of this article for himself) and let a transversal cut its three sides internally or externally; namely, let AB cut the transversal in *c*, BC in *a*, and CA in *b*. Then will either one or three of *a*, *b*, *c*, be in sides produced, and

$$\mathrm{A}c\times\mathrm{B}a\times\mathrm{C}b=\mathrm{B}c\times\mathrm{C}a\times\mathrm{A}b;$$

and the converse, namely, if *a*, *b*, *c*, be points taken on the three sides, having either one or three external, for which the above relation is true, then those three points are in the same straight line. In the language of Euclid, the ratio compounded of the three ratios of A*c* to B*b*, B*a* to C*a*, and C*b* to A*b*, is the ratio of a line to its equal.

This proposition is now frequently demonstrated in elementary works on geometry as follows:—From any one of the vertical points, A, B, C, draw a parallel to the side of the triangle which does not pass through that point; from C, for instance, draw CM parallel to AB, cutting the transversal in M. Then we have two pairs of similar triangles, MC*b*, *c*A*b*, and *a*B*c*, *a*CM, which give

$$a\mathrm{C}:\mathrm{CM}::a\mathrm{B}:\mathrm{B}c$$
$$\mathrm{CM}:\mathrm{C}b::\mathrm{A}c:\mathrm{A}b$$
$$\text{or } \mathrm{C}a:\mathrm{C}b::\mathrm{A}c\times\mathrm{B}a:\mathrm{A}b\times\mathrm{B}c;$$

whence the proposition required is obvious. The converse readily follows by indirect demonstration.

Let any point P be taken inside or outside of the triangle ABC, and let AP, BP, CP, cut BC, CA, AB in *a*, *b*, *c*. Then either one or three of the points as *a*, *b*, *c*, are internal.

$$\mathrm{A}c\times\mathrm{B}a\times\mathrm{C}b=\mathrm{B}a\times\mathrm{C}b\times\mathrm{A}c,$$

which is proved by using the former property in the triangle AB*a* with the transversal CP*c*, and the triangle A*a*C with the transversal BP*b*. The converse is also easily proved, namely, that if *a*, *b*, *c* be so taken on the sides with one or three internal as to satisfy the above relation, then A*a*, B*b*, C*c* all meet in one point.

The same proposition as the first is true of any polygon whatsoever: thus, let ABCDE be a pentagon, the sides of which are cut externally or internally by a line, namely, AB in *c*, BC in *d*, CD in *e*, DE in *a*, EA in *b*; then

$$\mathrm{A}b.\,\mathrm{B}c.\,\mathrm{C}d.\,\mathrm{D}e.\,\mathrm{E}a=\mathrm{A}c.\,\mathrm{B}d.\,\mathrm{C}e.\,\mathrm{D}a.\,\mathrm{E}b.$$

For let BD and BE meet the transversal in *m* and *n*: then the three triangles BDC, BED, BAE are cut by a transversal, giving

$$\mathrm{B}m.\mathrm{D}e.\mathrm{C}d=\mathrm{D}m.\mathrm{C}e.\mathrm{B}d$$
$$\mathrm{D}m.\mathrm{E}a.\mathrm{B}n=\mathrm{B}m.\mathrm{D}a.\mathrm{E}n$$
$$\mathrm{E}n.\mathrm{A}b.\mathrm{B}c=\mathrm{B}n.\mathrm{E}b.\mathrm{A}c;$$

by multiplication of which the theorem follows.

If the transversal be parallel to either of the sides, the two segments, which are then infinite, are to be considered as equal, and removed from both sides of the equation.

In the article Projection a test is given which, being satisfied, shows that a proposition is true of any figure, if it be true of any one of its projections. This test is satisfied in all the preceding cases, so that it is enough to prove any one case of these propositions, that is, for any one projection of the figure. Now there is no case in which they are obviously true, à *priori*, except for that projection in which the transversal becomes the vanishing line, or all the segments become infinite. If we put the first proposition of all in this form

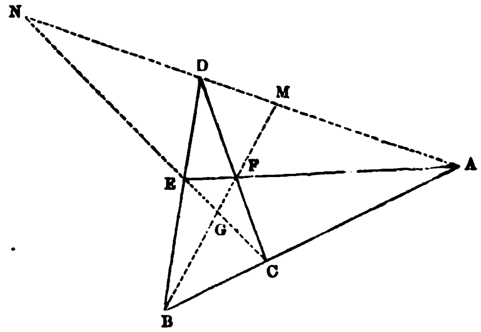
$$\frac{\mathrm{A}c}{\mathrm{A}b}.\frac{\mathrm{B}a}{\mathrm{B}c}.\frac{\mathrm{C}b}{\mathrm{C}a}=1,$$

it is obviously true when the line *abc* is at an infinite distance, each of the ratios being then unity. It would not be safe, upon the proof given in the article cited, to allow this extreme case of projection to enter into the theorem: nevertheless, other proof might be given, which would make this very simple and perceptible instance, the truth of which is seen at once, sufficient evidence of all the others. We mention this only to show the very great power of the geometry of projections: our limits do not allow of our entering further into the subject.

The theory of transversals may be made useful in surveying, particularly in military surveying: as an instance take the following. There is an inaccessible point A, from which to B it is required to find the distance without any instruments except signal-poles and a measuring-line. At B set up a signal, and another, C, at a convenient distance between B and A. Choose another signal-point, D, and between D and B set up a signal at E, and another at F, between D and C, and also between E and A. All this must be done by trial. Then measure DE, EB, DF, FC, and BC. The triangle DBC, cut by the transversal EFA, gives the following relation:—

$$\mathrm{DE}.\mathrm{BA}.\mathrm{CF}=\mathrm{EB}.\mathrm{CA}.\mathrm{FD}$$
$$\text{or } \mathrm{DE}.\mathrm{CF}.\mathrm{BA}=\mathrm{EB}.\mathrm{FD}\,(\mathrm{BA}-\mathrm{BC})$$
$$\text{whence } \mathrm{BA}=\frac{\mathrm{EB}.\mathrm{FD}.\mathrm{BC}}{\mathrm{EB}.\mathrm{FD}-\mathrm{DE}.\mathrm{CF}}$$

The projection of figures may throw them into such different forms that lines which, in Euclid's mode of speaking, would be called sides, become diagonals, and *vice versâ*. The distinction of diagonal and side therefore becomes an incumbrance, and a new mode of viewing polygons is introduced, of which we shall now give an instance. A figure contained by four straight lines is, generally speaking, one which has six points: since four straight lines meet two and two in six points; thus, the four-sided figure E F B C has the six points E, F, B, C, D, A. If all these points be joined two and two, we have the additional lines B F, C E, D A, of which only the two first are commonly called diagonals: but all three have common properties. We shall prove the following by the extreme method of projection already alluded to, leaving the reader to verify it by the theory of transversals: each of the diagonals is harmonically divided by the other two; that is,



A M : M D : : A N : N D
C G : G E : : C N : N E
B G : G F : : B M : M F

To show the first: project the figure so that N B shall be the vanishing line. Then D E C A will be projected into a parallelogram, and M G into a parallel to D E and A C passing through the intersection of the diagonals: consequently, in the projection, A M = M D, and we have, also in the projection,

$$\frac{AM}{MD} \cdot \frac{DN}{NA} = 1;$$

for D N and N A are both infinite, and D N ÷ N A is unity. Now by the test in PROJECTION, which is here satisfied, this proposition must be always true, whence in our figure we have A M : M D : : A N : N D. Similarly the other proportions may be proved.

Here then is the easiest way of dividing a line in harmonic proportion. Let A D be given, and M: it is required to complete the harmonic division by finding N. Take any point, B, and draw D B, M B, A B. Choose any point, F, in M B, and produce D F and A F to C and E. Then C E produced to meet A D will give the point N required. No instrument is wanted, except the ruler and pencil, and it is a good exercise in drawing to find out by repeated instances that, let B be taken where it may, there is but one position of N. It is also a good test of the straightness of a ruler.

TRANSVERSE, a name often given to one of the axes of a figure, usually that of greatest magnitude or which goes most directly across the figure. Thus the longer axis of an ellipse or hyperbola is called the transverse axis: but sometimes the shorter axis is so called. Properly speaking, it ought to be only a term of relative distinction: either axis is transverse to the other.

TRAPE'ZIUM, TRAPEZOID. The first word (*τραπέζιον*, a little table) is used by Euclid for, or at least defined to be, any four-sided figure which is not a parallelogram. The second word, formed from the first, has been used by various writers, and in different senses. A trapezoid, says Harris ('Lex. Tech.') is a solid irregular figure, having four sides not parallel to one another: Hutton repeats this, but says it sometimes means a trapezium, two (only) of whose sides are parallel to each other. What the *solid* figure with four *sides* means we do not know: but as the word is never used, we omit all inquiry about it. Words however are so scarce in mathematical language, that it is a pity when any become obsolete. If we were to suggest meanings for these terms, we should propose that *trapezium* should be the general word for *plane* four-sided figures, parallelograms and all; and that *trapezoid* should denote a four-sided figure whose sides are not in the same plane. Perhaps this is what was intended by the *solid* figure of four sides: if so, it was particularly unnecessary to state that the sides are not parallel.

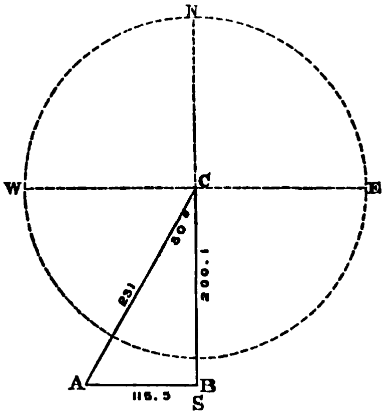
TRAVERSE, in Law, is a contradiction of some matter of fact alleged in pleading by the opposite party. Generally all matter of fact, that is material, ought to be either confessed and avoided, or traversed; and if a party justifies an act as to one particular time and place, or confesses and avoids in one respect, he ought to traverse it as to all other. Otherwise what is materially alleged will be taken to be admitted. Traverse of an immaterial fact, or of a mere supposition, or of inducement, is bad, for it is not an answer to the action. If a traverse is tendered as to a material point by one party, the other must accept it; he cannot waive it and tender another traverse.

In criminal pleading traverse of an indictment is the taking issue and denying some material point in it. Not guilty is a general traverse, which throws on the prosecutor the necessity of proving all the material facts.

TRAVERSE SAILING. [RECKONINGS AT SEA.]

TRAVERSE TABLE. In navigation two tables bear this name; the one is the list of courses, distances, northings, southings, eastings, and westings, in which they are arranged for the convenience of addition, so that difference of latitude and departure may be readily deduced in dead reckoning, when a ship cannot lay her course, but sails in various directions, or upon a traverse as it is called. [RECKONINGS AT SEA.] That which is more properly called a Traverse Table, is one from which the various northings, southings, &c. as above are gathered.

The following figure will explain its principles:—



Suppose a ship at C sails S. 30° W., a distance of 231 miles; according to the usual mode of construction, the side C B would represent the meridian of the ship, and, therefore, the distance C B would be the difference of latitude; while A B would be the departure from that meridian, and A C the distance sailed, the angle C being the course 30°, as marked. It will be seen that only four parts enter into consideration, because the angle A is known (as the complement) when C is known, and the ∠ B is a right angle: any two of these four parts being known, the others may be found by trigonometry. But to save the trouble of logarithmic calculation (which such involves), a large number of right-angled triangles have been purposely computed, and varied according to the magnitude of the course or ∠ C: being arranged in columns headed by the amount of such angles: the above example would appear in the table thus among the distances:—

Course 30°.

Dist.	Diff. Lat.	Dep.
231	200·1	115·5

Comparing this with the figure, the nature of the table will be evident, as each line represents three parts of a triangle, as taken in connection with whatever ∠ C heads the list or page.

The artisan and engineer would be greatly benefited if these tables were more in use. As it is, they are too generally considered as adapted to navigation principally, and the terms used favour this misapprehension. If, however, such tables were published with the substitution of ∠ C for "course;" *perpendicular* for "difference of latitude," and *base* for "departure," the difficulty would be at once removed. Such tables supersede calculation of right-angled triangles entirely, so far as application to practice demands. How far the facility thus offered would tend towards a superficial standard of mental attainment is another consideration: but such are the capabilities of the traverse table.

TRAVERSES, in Fortification, are usually masses of earth which are raised at intervals across the terreplein of a rampart or across the covered-way of a fortress: their positions in the covered way are indicated at *t*, *t*, &c. [FORTIFICATION.] On a rampart they serve to protect the guns and men against the effects of a ricocheting or enfilading fire, which might otherwise dismount the former, and compel the latter to abandon the parapet; and in the covered-way, besides serving for similar purposes, they constitute retrenchments behind which the defenders may keep up an annoying fire of musketry upon the enemy, should the latter attempt to force his way along the branches of that work. On this account they are provided with banquettes, or steps, on which the defenders may stand to fire over them. Such a work, when formed in a direction parallel to a rampart or parapet, on its interior side, for the purpose of securing the defenders against a fire from the ground in their rear, is called a parados.

Palisades are planted along the banquettes, in order to prevent the assailants from suddenly passing over the traverses; and at the passage between each traverse and the interior side of the glacis, is a strong gate, or barrier, which is closed in the event of the defenders being obliged to retire from one traverse to the next, or to abandon the covered-way entirely.

As, at the time of an assault being made at the salient part of a covered-way, the defenders might be bayoneted in attempting to retire along the passages between the traverses and the glacis (those passages being then commanded by the enemy), it has been recommended to form other passages about four feet wide between the opposite extremities of the traverses and the top of the counterscarp; and, in order that the retreat may be effected without molestation, a line of palisades is planted from each traverse to the next along the middle of the covered-way, in addition to the line which is always planted along the foot of the interior slope of the glacis.

The traverses, like other parapets, are usually above eighteen feet thick at the upper part, in order that they may not be immediately destroyed by the heavy artillery of the enemy; but the French engineers recommend that all the traverses in the covered-way, except those which are close to the re-entering places of arms, L, L [FORTIFICATION], should not exceed twelve feet in thickness, as it may be advantageous for the defenders to destroy them in the event of the enemy endeavouring to protect himself by them during the operation of cutting a trench across the covered-way for the purpose of making a descent into the ditch of the fortress.

TRAVESTY. [PARODY.]

TREACLE. [MOLASSES; SUGAR CULTURE AND MANUFACTURE.]

TREASON. This term, in its legal signification, is derived from the French *trahison;* and in conformity with this derivation, the offences designated by it in English law always contained the notion of treachery, or a breach of that allegiance supposed to be due from an inferior to a superior. Thus petit-treason was the murder of a husband by his wife, or a master by his servant, or a bishop by his subordinate in the church; and high treason consists in an attack upon the sovereign as the political head of the state. The former of these two kinds of treason was placed in another class of crimes by the statute of 9 Geo. IV., c. 31, s. 2, which made petit-treason murder only, and no greater offence. The only crime therefore now known to the law of England under this term is high treason, which, as it is composed of numerous acts and circumstances, constructively and remotely, as well as immediately, affecting the safety of the person of the sovereign, cannot be accurately described by any simple definition.

In early periods of the history of England, the law upon this subject was extremely vague and uncertain, in consequence of the great variety of acts which were held to constitute high treason as tending to diminish the power or dignity of the crown: killing the king's father or brother, or even his messenger, refusing to answer in the king's courts, and summoning an English subject to appear and defend himself in the court of a foreign prince, were deemed to be acts of treason. (3 'Inst.' 7; Hawkins's 'Pleas of the Crown,' b. 1, c. 17.) Indeed, immediately before the date of the statute of treasons, a knight was indicted for high treason in "usurping royal power within the king's realm," by assaulting another on the highway, taking his horse and detaining him until he paid 90*l.* (Hale's 'Pleas of the Crown,' vol. i., p. 80.) From these and many other instances which are to be found in law books, it appears that almost every act that could be in any way considered as a breach of the allegiance due to the king, or a constructive assumption of royal authority, was deemed to be high treason, as an "accroachment of royal power." This arbitrary state of the law became the cause of intolerable oppressions, and a petition to Edward III. from a parliament, which Mr. Hallam calls "one of the best that ever sat" ('Constitutional History,' vol. iii., p. 204), occasioned the statute 25 Edward III., commonly called the "Statute of Treasons." This enactment gave for the first time an intelligible definition of the crime of treason, and, notwithstanding the total change of national habits, still continues, after the lapse of five centuries, to be the governing law on the subject. Valuable as this law undoubtedly was in the comparatively rude times in which it was made, the inadequacy of its provisions to meet the complicated relations of a more refined state of society has frequently rendered supplemental statutes necessary, and has been the cause of those subtle and forced interpretations of its simple language, which have introduced scarcely less uncertainty and injustice into this department of the criminal law than prevailed before its enactment.

The several acts and circumstances constituting high treason by the "Statute of Treasons" are as follows:—1. Compassing or imagining the death of the king, the queen consort, or their eldest son and heir. 2. Violating the king's companion (by which is meant the queen consort), or the king's eldest daughter unmarried, or the wife of the king's eldest son and heir. 3. Levying war against the king within his realm. 4. Being adherent to the king's enemies in his realm, giving them aid and comfort in the realm or elsewhere. 5. Counterfeiting the king's great or privy seal. 6. Counterfeiting the king's money, or knowingly bringing false money into the realm counterfeit to the money of England, to merchandise and make payment withal in deceit of the king and his people. 7. Slaying the chancellor, treasurer, or the king's justices of either bench, justices in eyre, justices of assize, or any other justices assigned to hear and determine, being in their places, doing their offices. As several of the offences above enumerated are acts' of the mind, and consist in intention, the statute declares that in such cases the intention, in order to come within the meaning of the law, must be manifested by some open or *overt* act done towards the accomplishment of the traitorous intention. This provision, although by its position in the statute it is apparently limited to the offence of adhering to the king's enemies, has been held to apply to all the treasons before mentioned. (Hale's 'Pleas of the Crown,' vol. i. p. 108.)

The word "king," used in the first clause of the statute describing the offence of compassing the king's death, comprehends the case of a queen regnant, as she is invested by the constitution with full royal authority, and is entitled to the allegiance of her subjects. But the husband of the queen regnant is not within the words or meaning of the statute. The precise meaning of the words "compass" and "imagine" in this clause of the statute has been the subject of some discussion. Mr. Luders has thrown much light upon their signification by collecting the instances in which the same language has been used in writings contemporaneous with the statute; and although attempts have been made to give them a more enlarged signification, it is clear that they mean nothing more than "attempt" and "contrive." ('Considerations on the Law of High Treason in the article of Levying War,' p. 137.) If this be so, the meaning of this clause is sufficiently obvious to an ordinary reader, and would be certainly limited in his apprehension to attempts or contrivances against the natural life of the king. But by means of legal construction, the words have received a much wider meaning. Thus, a conspiracy to imprison or depose the king, which by the statute of treasons is not declared to be a substantive treason, has been repeatedly held to be high treason in the article of compassing his death, because, according to a saying of Machiavelli, "There is but a short interval between the prisons and graves of princes." Mr. Hallam justly observes, that "it seems not very reasonable to found a capital conviction on this sententious remark." It appears indeed formerly to have been questionable law, for Chief Justice Brooke, who compiled his 'Abridgment of the Law' at the commencement of the 16th century, expresses a doubt whether a design to depose the king be within this clause of the statute; "for," says he, "one may deprive the king of his crown, without designing his death;" and in confirmation of his view of the matter, he refers to the statutes which had been passed from time to time to remedy this defect in the Statute of Treasons. (Brooke's 'Abridgment,' tit. 'Treason,' fol. 24.) And in fact experience shows that the adoption of this proposition would frequently lead to a false result, several instances of rebellion having occurred in English history, in which the designs of the rebels would have been wholly defeated by the death of the king, whose name they designed to employ. ('Constitutional History,' vol. iii., p. 208.) Nevertheless the doctrine that a design to depose is an overt act of compassing the death of the king, has been repeatedly confirmed by treatises of the highest authority, as well as by judicial decisions. (Foster's 'Discourse on High Treason,' p. 196; Howell's 'State Trials,' vol. xxiv., p. 1361; vol. xxv., p. 725.) A still more extensive signification has been given to these words of the statute by the forced interpretation that a conspiracy to levy war against the king and also consulting with a foreign enemy to invade the realm, were overt acts of treason in the article of compassing the king's death. (Hale's 'Pleas of the Crown,' vol. i., p. 120.) This mode of reading the plain words of a penal statute was obviously liable to serious objections and led to great oppression and injustice; "such a method," as Sir M. Hale says, "admitting of no limits or bounds, but running as far as the wit or invention of accusers, and the odiousness and detestation of persons accused, will carry men." ('Pleas of the Crown,' vol. i., p. 86–7.)

The doctrine of constructive treason having been brought into prominent notice and much discussed in the trials of Hardy, Horne Tooke, and others in 1794, the statute 36 Geo. III., c. 7, was passed with a view of superseding the necessity of resorting to any such modes of interpretation for the future. This statute, which, although originally in force only for the life of George III., was made perpetual by the stat. 57 Geo. III., c. 6, enacted that "if any person shall, within the realm or without, compass, imagine, invent, devise, or intend death or destruction, or any bodily harm tending to death or destruction, maim or wounding, imprisonment, or restraint of the person of the king, or to deprive or depose him from the style, honour, or kingly name of the imperial crown of this realm, or of any other of his majesty's dominions or countries, or to levy war against his majesty within this realm, in order by force or constraint to compel him to change his measures or councils, or in order to put any force or constraint upon, or to intimidate or overawe both Houses or either House of Parliament, or to move or stir any foreigner or stranger with force to invade this realm, or any other of his majesty's dominions or countries under the obeisance of his majesty; and such compassings, imaginations, inventions, devices, and intentions, or any of them, shall express, utter, or declare, by publishing any printing or writing, or by any overt act or deed, every such offender, being legally convicted upon the oath of two lawful and credible witnesses, shall be adjudged a traitor, and suffer as in cases of high treason." It was no doubt the intention of the legislature that this statute should put an end to all artificial constructions of the statute of Edward III.; nevertheless the practice of resorting to these forced interpretations has been continued, and sanctioned by the approbation of the judges in several subsequent prosecutions for high treason. ('Sixth Report of Commissioners on Criminal Law,' p. 16.)

The second kind of treason declared in the Statute of Treasons is the violation of females of the royal family, and was obviously intended to preserve the purity of the succession to the throne. With a view to this object, the law has been held to apply to a criminal connection by consent as well as to a forcible violation. It is worthy of remark, as one of the numerous circumstances showing the inapplicability of this ancient law to modern times, that a queen regnant, whether married or single, is not within this clause of the statute.

The third species of treason above mentioned is "levying war against the king in his realm." It amounts to treason under this clause of the statute to take arms against the king, not only with the object of destroying him, but where it is intended by open violence to reform religion or the laws, or to remove evil councillors, or other grievances, whether real or pretended. (Hawkins's 'Pleas of the Crown,' b. i., c. xvii., s. 25.) The plain words of this clause of the statute have been still more extravagantly extended by legal construction than those of the clause relating to compassing the king's death. Thus riotous assemblies, where the object has been to destroy *all* property of any particular class, such as to pull down all meeting-houses, or to destroy all inclosures, have been held to be treason in all who join them, by reason of the generality of the design. This doctrine has, however, been much questioned in recent times; and to the extent formerly contended for, would probably not be countenanced by the judges at the present day. (Luders, 'On Constructive Treasons;' 'Sixth Report of Commissioners on Criminal Law.') Indeed the necessity for constructive extensions of the words of this clause, which might have been plausibly argued from the omission in the Statute of Treasons to notice conspiracies or preparations to levy war against the king, has been entirely removed by the above-mentioned statute of the 36 Geo. III., c. 7.

The fourth kind of treason mentioned in the Statute of Treasons is adherence to the king's enemies. The enemies here mentioned are foreign powers and states with whom the king of England is at war, and who owe him no allegiance; and, therefore, an adherence to British subjects in a state of rebellion against the king will not constitute treason under this clause, although it may amount to treason in the article of levying war. This kind of treason must, like compassing the king's death, or levying war against him, be evidenced by some overt act, such as treacherously surrendering a fortified place, or supplying arms, or giving information to an enemy.

The fifth treason mentioned in the statute is counterfeiting the king's seals; and this offence would now be punishable as forgery only. The clause in the Statute of Treasons, which declares the offence of counterfeiting the king's coin to be high treason, has been repealed by the stat. 2 Will. IV., c. 34; and the crime itself has been by the same enactment divided into distinct classes, as felonies and misdemeanors, with a graduated scale of punishments.

The last species of treason above referred to is the offence of slaying the chancellor or the judges, which still continues to be high treason. This part of the law is, however, obviously imperfect, as it does not comprehend the barons of the exchequer, who at the present day are the king's superior justices as fully as the judges of the other courts of Westminster Hall; whereas it includes the justices in eyre, whose office has long since been abolished.

Besides the several treasons above enumerated, a large class of offences has been created by various statutes passed from time to time in the reigns of Elizabeth and James I., with the avowed object of protecting the Protestant religion from the designs of Roman Catholics. But as many of these statutes have not been the subject of prosecution for nearly three centuries, and many others have never been enforced at all, they may perhaps be considered as virtually obsolete, and do not require to be particularly noticed in this article. ('Sixth Report of Commissioners on Criminal Law,' p. 35.)

With a view to diminish the peculiar disadvantage under which a person charged with treason was supposed to labour in having to defend himself against a prosecution in which so powerful an adversary as the crown was interested, several privileges as to process, evidence, and trial have been given by statute to persons so accused. It is declared by the stat. 7 Will. III., c. iii., s. 2, that no person whatsoever shall be indicted, tried, or attainted of high treason or of misprision of treason, but upon the oaths of two lawful witnesses, unless the party indicted shall willingly, without violence, in open court confess the same. And by the third section of the same statute, it is declared that if two or more distinct treasons of divers heads or kinds shall be alleged in one indictment, one witness produced to prove one of the treasons, and another witness to another of the treasons, shall not be deemed to be two witnesses to the same treason within the meaning of the statute. The same statute of the 7 Will. III., c. 3, also enacted that no person should be tried for any treason (except an attempt to assassinate the king) unless the indictment be found within three years after the offence committed. Moreover, the prisoner is to be furnished with a copy of the indictment five days, and a copy of the panel of jurors two days, before the trial. He is to have the same compulsory process to enforce the attendance of his witnesses as was at the time of the statute exclusively applicable to the prosecutor's witnesses; and he is to have full defence by counsel selected by himself and expressly assigned to him by the court. The stat. 7 Anne, c. 21, materially extended these privileges by directing that all persons indicted for high treason, or misprision thereof, shall have not only a copy of the indictment, but also a list of all the witnesses to be produced, and of the jurors impanelled, with their professions and places of abode respectively, delivered to him ten days before the trial, and in the presence of two witnesses, the better to prepare him to make his challenges and defence.

It may perhaps be doubted whether these indulgences are founded upon any true principles of criminal jurisprudence. If justice requires them, they should be generally applied to all crimes; and at all events there seems to be no sufficient reason for giving a different measure of advantage to persons accused of high treason from that afforded to persons accused of many other offences. So obvious indeed was the inconsistency of giving greater privileges and advantages to a person charged with an attempt to kill the king than were permitted in the case of a similar attempt upon the life of a private person, that upon occasion of an attack upon George III., in the year 1800, an act of parliament was passed to remove it. The statute 39 & 40 Geo. III., c. 93, enacts that in all cases of high treason, in compassing or imagining the death of the king, and misprision of such treason, where the overt act alleged shall be the assassination or killing of the king, or any direct attempt against his life, or against his person, whereby his life may be endangered, or his person suffer bodily harm, the offender may be indicted, arraigned, tried, and attainted, in the same manner, and according to the same course and order of trial in every respect, and upon the like evidence, as if such person stood charged with murder; and none of the provisions contained in the above-mentioned acts of 7 Will. III., c. 3, and 7 Anne, c. 21, shall extend to any indictment for this species of treason. A clause in a subsequent statute (6 Geo. IV., c. 50, s. 21) provides that the list of the jury shall in all indictments for treason, or misprision of treason, in other courts than the King's Bench, be delivered at the same time with the copy of the indictment, and ten days *before* the arraignment; and in the court of King's Bench it may be delivered *after* the arraignment, but ten days before the trial. This statute does not extend to the case of attempts upon the life of the king mentioned in the stat. 39 & 40 Geo. III., c. 93. By the stat. 5 & 6 Vict., c. 51, the provisions of the stat. 39 & 40 Geo. III., c. 93, are extended to "all cases of high treason in compassing or imagining the death or destruction of the queen, or in compassing or imagining any bodily harm tending to the death or destruction, maiming, or wounding of the queen, and of misprision of such treason, when the overt act alleged shall be any attempt to injure in any manner whatsoever the person of the queen;" and such cases are expressly excepted from the operation of the above-mentioned statutes of 7 Will. III., c. 3; 7 Anne, c. 21; and 6 Geo. IV., c. 50, s. 21.

The judgment in high treason is that the offender shall be drawn on a hurdle to the place of execution, and there be hanged by the neck until he is dead; that afterwards his head shall be severed from his body; and his body, being divided into four quarters, shall be at the disposal of the crown. This punishment was substituted by the statute 54 Geo. III., c. 146 for the ancient and barbarous sentence which required that the person convicted should be hanged, but taken down alive, and then that his bowels should be taken out and burnt before his face. By the 2nd section of stat. 54 Geo. III., c. 146, authority is given to the crown by warrant under the sign manual, countersigned by a secretary of state, to alter this sentence, and to direct that, instead of the ignominious part of it, the party shall be beheaded whilst alive.

TREASURE-TROVE, in legal Latin called *thesaurus inventus*, is a branch of the revenue of the crown by the law of England. Where coin, plate, or precious metals are found hidden in the earth or any private place, and the owner or person who deposited them is unknown, the property becomes vested in the king by virtue of his prerogative. But if the owner is known, or is ascertained after the treasure is found, the property belongs to him, and not to the king. The civil law gave treasure found in general to the finder; but if found accidentally in another man's land, half was given to the finder, and half to the owner of the land. And so if it was found in the land of the emperor, it was to be equally divided between him and the finder. ('Inst.,' lib. ii., tit. i., § 39; 'Cod.,' lib. x., tit. 15.) Grotius says that the title of the prince to treasure-trove had in modern times been so generally established in Europe as to have become "jus commune et quasi gentium" ('De Jure Belli et Pacis,' lib. ii., c. viii., § 7). The law of England adopts the definition of treasure-trove from the civilians as "vetus depositio pecuniæ cujus dominus ignoratur' (Paulus, lib. xxxi., § 1); and to entitle the crown to the property, it must appear to have been hidden or deposited by some one who at the time had the intention of reclaiming it. Whenever, therefore, the intention to abandon appears from the circumstances—as for instance, where the property has been found in the sea, or in a pond or river, or even openly placed upon the surface of the earth—it belongs to the finder. In England, the concealment of treasure-trove from the king was formerly a capital offence; at the present day it is a misdemeanor only. Ancient coins or other valuable articles found, are now declared to be so far the property of the finders that they may have the value paid to them. This has been directed by an order in council in order to prevent the destruction of such objects for the mere value of the material.

TREASURY, a department of the British government which controls the management, collection, and expenditure of the public revenue. It is the business of another department, the Exchequer, to take care that no issues of public money are made by the Treasury without their being in conformity with the authority specially enacted by parliament. When money is to be paid on account of the public service, this is almost always done on the authority of a Treasury warrant; and in other cases the countersign of the Treasury is requisite. The Board of Treasury consists of the prime minister and the chancellor of the Exchequer. The real office which the premier holds is generally that of first lord of the Treasury. There are also four junior lords, who have usually seats in parliament, as have also the two joint secretaries of the Treasury. The departments immediately subordinate to the Treasury are the boards of Customs and of Trade, and the Post-Office, the various officers in which are to a great extent appointed by the lords of the Treasury; and this constitutes an important part of the patronage of the ministry. The duties of the Board of Treasury are heavy and multifarious, all exceptional cases in matters relating to the revenue being referred to it. The offices of the Treasury are in Whitehall. The first lord of the Treasury receives 5000*l*. a-year; two secretaries of the Treasury receive 2500*l*. a-year each, and the assistant-secretary 2000*l*. a-year; the solicitor of the Treasury receives 2850*l*. a-year; four commissioners of the Treasury receive 1200*l*. a-year each; and other officers receive sums varying from 1000*l*. to 1500*l*. each.

TREATIES, CHRONOLOGICAL TABLE OF. A treaty (immediately from the French *traité*) means literally that which has been drawn up, or, in other words, arranged and agreed upon, by two or more parties, who are accordingly called the contracting parties. It is in fact the same word with contract. The term in its several variations is now employed by most of the nations of Europe—by the Italians, the Spaniards, the Germans, the Dutch, &c., as well as by the English and the French—to designate the conventions or agreements which governments make with one another. By the Romans a treaty was commonly called *foedus*, a word of unknown or uncertain etymology. From *foedus* we have formed our federation, confederacy, &c.

Although a treaty is commonly defined to be an agreement made with one another by two or more governments, it is not necessary that the party to a treaty should always be an absolutely sovereign and independent power or political society. Communities, or even individuals, which are subjects in many or in all other respects, may be empowered to enter into treaties. Such engagements, however, are for the most part only to be depended upon so long as they are for the advantage of the one party as well as of the other. Hence the best and most durable treaty is always that which is the fairest and the most equal. But the main purpose and utility of a treaty, after all, is not that it may secure certain advantages to either party, but that it makes clear and fixes those relations between the two which would otherwise remain obscure, indeterminate, and subject to continual misconception or controversy.

We proceed to give a *Chronological Table* of the more important treaties between the principal civilised nations, beginning with that of 1217, the first formal treaty of England, and stating briefly the chief objects of each.

1217, Sept. 11. Treaty at Kingston between Louis of France and the Regent in the name of Henry III., by which Louis abandoned his attempt on the English crown.

1274. Treaty between Edward I. and Guy Earl of Flanders. This is the first recorded commercial treaty of England. There had been a petty quarrel with the Flemings, chiefly between the fishermen of the two countries; and England had prohibited the exportation of wool, to the great detriment of the manufactures of the Flemings. These differences were accommodated by this treaty; but fresh ones broke out apparently, as treaties of commerce with Flanders are frequent after this period.

1308. Commercial treaty with Portugal, and in the same year another with Spain. Ferdinand of Castile wishing for a "mutual free correspondence" between his subjects and England, and Dionysius of Portugal desiring to "strengthen the agreement and correspondence already on foot between the merchants of both nations."

1328. Treaty of Northampton with Robert Bruce, by which the independence of Scotland was recognised.

1356. The Golden Bull, a convention of the German sovereign princes, settled at Nürnberg, by which the mode of electing the Emperor was determined.

1360, May 8. Peace of Bretigny, near Chartres, between England and France, whereby England retained Gascony and Guienne, acquired Saintonge, Agenois, Perigord, Limosin, Bigorre, Angoumois, and Rovergne, and renounced her pretensions to Maine, Anjou, Touraine, and Normandy; England was also to receive 3,000,000 crowns, and to release King John, who had been long prisoner in London.

1381, Aug. 8. Treaty of Turin, between Venice and Genoa.

1390. Treaty between the Sultan Bajazet and the Greek Emperor, John Paleologus.

1420, May 21. Treaty of Troyes, between England, France, and Burgundy, stipulating that Henry V. should marry Catherine, daughter of Charles VI., be appointed Regent of France, and after the death of Charles should inherit the crown.

1423, April 17. Treaty at Amiens between England and Burgundy.

1435, Sept. 22. Treaty of Arras between France and Burgundy.

1438. The Pragmatic Sanction settled in France, regulating the election of bishops, and moderating the power of the pope.

1453. The first alliance entered into between the French and Swiss.

1464. A league, designated "For the public good," formed between the Dukes of Burgundy, Brittany, and Bourbon, and others, against Louis XI. of France.

1465. Treaty of Conflans, between Louis XI. and the chiefs of the above league.

1468. Treaty of Peronne, between Charles Duke of Burgundy and Louis XI., who was forced to confirm the stipulations of Arras and Conflans.

1475. The Peace of Picquini, concluded between Edward IV. of England and Louis XI. of France.

1475. Charles the Bold, of Burgundy, concluded a treaty with the French king, but speedily afterwards leagued against him with Edward IV. of England, and the Duke of Brittany. Louis XI., on the other hand, entered into a treaty with the Switzers, and succeeded ultimately in becoming an ally of England.

1482. The Treaty of Arras, between Maximilian of Austria, the husband of Mary of Burgundy, and Louis XI. of France, whereby Margaret, daughter of the former, was espoused to the dauphin, son of the latter, with Artois and Burgundy as a dowry.

1497. Treaty between England and Scotland, by which Perkin Warbeck was compelled to quit the latter kingdom.

1501. Treaty between Louis XII. of France and Ferdinand of Spain, for the division of the kingdom of Naples.

1508, December 10. The League of Cambray against the republic of Venice, comprising the Pope, the Emperor, and the kings of France and Spain.

1510. Holy League against Louis XII. of France.

1514. France obliged to sue for peace, which was obtained from the Pope, by promising to abolish the Pragmatic Sanction; from the King of Spain, by uniting his grandson, the Duke of Ferrara, to Renée, daughter of the King of France; and from England, by Louis XII. espousing Mary, sister of Henry VIII.

1516, August 16. The Treaty of Noyon.

1525. A Treaty concluded between France and England.

1526. Concord of Madrid. Francis I., to release himself from captivity, signed a treaty with Charles V., surrendering Burgundy, Artois, Flanders, &c., and renouncing all pretensions to Italy.

1527. A Treaty of mutual obligation entered into between France and England; and in the same year a fresh treaty, for the purpose of carrying war into Italy to restore the Pope to liberty.

1529, August 5. The Peace of Cambray.

1529, December 31. The League of Smalcald in Franconia, entered into between the Elector of Brandenburg and other princes of Germany, in defence of Protestantism.

1532, June 23. A new Treaty of Alliance ratified between the kings of England and France.

1532, August 2. The Treaty of Nürnberg ratified.

1538, June 18. Treaty of Nice, between Francis I. and Charles V.

1544. League between England and the Emperor Charles V. against France, shortly after which peace was concluded with France, and signed at Cressy in Valois.

1548, May 15. The Interim granted by the Emperor Charles V. to the Protestants of Germany.

1549. Peace ratified between France and England. Boulogne restored to France.

1551, October 5. Treaty of Friedwald, between France and the Protestant princes of Germany.

1552, January 15. Treaty of Chambord, confirming the league between France and the Protestant princes of Germany.

1552, August 12. Treaty of Passau, ratified between Charles V. and the Protestant princes of Germany. Freedom of religion established.

1555. Peace of Religion concluded at Augsburg,—a confirmation of the Treaty of Passau, establishing the free exercise of the Protestant religion.

1556. England entered into an alliance with Spain against France.

1559. Peace of Cateau Cambresis, between France, Spain and Piedmont. France ceded Savoy, Corsica, and nearly 200 forts in Italy and the Low Countries.

1560. Peace ratified between England, France, and Scotland.

1561. Treaty of Wilna, between the Northern Powers.

1564, April 29. Peace ratified between France and England.

1570. Peace of St. Germain.

1570, December 13. Peace of Stettin, between Sweden and Denmark.

1571. Spain, Venice, and the Pope combine against the Turks, who were endeavouring to subdue Cyprus.

1572. Peace concluded between England and France.

1576. November 8. Pacification of Ghent, by which foreign troops were expelled from the Netherlands and the Inquisition abolished.

1576. The League begins in France.

1579, January 22. The Union of Utrecht, formed by Holland, Utrecht, Zealand, Friesland, and Guelderland, by which the republic of Holland was constituted. Overyssel joined in 1580, and Groningen in 1594.

1598, May 2. Peace ratified at Vervins between France and Spain. Spain restores her conquests of Calais, Amiens, &c.

1603. A Treaty between James I. of England and Henry IV. of France, in order to support the States-General of Holland.

1604, August 18. Peace between England and Spain ratified.

1609, April 4. A Truce of twelve years between the Spaniards and Dutch.

1610. Treaty of Halle, between the Protestant princes of the empire.

1610. League of Würzburg, between the Roman Catholic princes of the empire.

1613. Peace of Siöröd, concluding a war of two years between Sweden and Denmark.

1619. Peace between France and Spain. Marriage of Louis XIII. with Anne of Austria, infanta of Spain.

1620, July 3. Peace of Ulm, by which Frederic V. lost Bohemia.

1626. League of the Swedes, Dutch, and the Protestant princes of Germany, against the Emperor.

1629, April 14. Peace ratified with France.

1629, May 22. Peace of Lubeck, between the Emperor and King of Denmark.

1630. League of France with the Protestant princes of Germany, Gustavus Adolphus of Sweden, and Holland, against the house of Austria, in Germany and Spain.

1630. England also acceded to the above alliance, with a view of procuring the restoration of the Elector Palatine.

1630, October 13. Peace of Ratisbon, between France and the Emperor, terminating the war for the Mantuan succession.

1630, November 27. Peace proclaimed between England and Spain.

1631, January 13. Subsidising alliance of France with Sweden.

1631, April. Alliance of Leipzig, between the Elector of Saxony and the Protestant princes.

1631. Treaty of Chierasco, by which the Duke of Nevers finally takes possession of his Mantuan territories.

1633, March. Treaty of Heilbron, between Sweden and the Northern Protestant states of Germany, after the death of Gustavus Adolphus.

1635, February 28. Alliance between France and Holland.

1635, May 30. Peace of Prague, between the Emperor and the Elector of Saxony.

1648, January 30. Peace of Münster, between Spain and the Dutch. Independence of Holland fully recognised.

1648, October 24. The Peace of Westphalia signed at Münster and at Osnaburg, between France, the Emperor, and Sweden; Spain continuing the war against France. By this peace the principle of a balance of power in Europe was first recognised, and the independence of the republics of Switzerland and the United Provinces of the Netherlands recognised.

1654, April 5. Peace ratified between the Dutch and the Commonwealth of England.

1655, November 3. Articles of Peace signed between England and France.

1656, November 10. Treaty of Liebau, which annulled the feudal subjection of the duchy of Prussia to the crown of Sweden.

1657, March 23. Treaty of Alliance between England and France against Spain.

1657, May 27. Alliance of Vienna, between Poland, Denmark, and the Emperor, against Sweden.

1659, May 21. Treaty of the Hague, between England, France, and Holland, to maintain the equilibrium of the North.

1659, November 7. Peace concluded between France and Spain, by the Treaty of the Pyrenees.

1660, May 3. The Peace of Oliva ratified between Sweden, Poland, Prussia, and the Emperor. Esthonia and Livonia given up to Sweden.

1660, May 27. Peace of Copenhagen, between Sweden and Denmark.

1661, June 23. Treaty of Alliance between England and Portugal.

1663. France entered into a defensive alliance with Holland and Switzerland.

1664, September 7. The Truce of Temeswar concluded between Turkey and Germany.

1666, January 26. The Danes entered into a league with the Dutch against England.

1667, July 25. Peace of Breda concluded between England, France, Holland, and Denmark.

1668, January 28. A Treaty of Alliance ratified between the States-General and England against France, for the protection of the Spanish Netherlands; Sweden afterwards joining the league: it was known as the Triple Alliance.

1668, February 13. Peace of Lisbon concluded between Spain and Portugal through the mediation of England. Independence of Portugal acknowledged by Spain.

1668, May 2. Peace of Aix-la-Chapelle, between France and Spain, signed. France yields Franche Comté, but retains her conquests in the Netherlands.

1669, May 7. Treaty of the Hague, between Holland and Portugal: the Dutch allowed to retain their conquests in India.

1672. Treaty between France and England (February 12), and Sweden (April 14), against Holland.

1672, August 30. An Alliance entered into between the Emperor, Spain, and Holland, against France.

1673, June 16. Peace of Vossem, between the Elector of Brandenburg and France; the former engaging not to assist the Dutch.

1674, February 19. Peace of Westminster, between England and Holland.

1678, January 10. Treaty concluded between England and Holland, by which Holland detached Charles II. from the interests of France.

1678, August 10. Peace of Nimeguen concluded between France and Holland. Spain accedes to the peace September 17, giving up Franche Comté, &c.; the Emperor on February 5 following; and Sweden on March 29.

1679, June 29. Peace of St. Germain en Laye concluded between France, Sweden, and the Elector of Brandenburg.

1679, September 2. Peace of Fontainebleau, between France and Denmark.

1683, March 31. Alliance of Warsaw, between Austria and Poland, against Turkey, in pursuance of which John Sobieski assisted in raising the siege of Vienna, on Sept. 12.

1684, August 15. Truce of Ratisbon concluded by France with Spain and the empire, terminating the war of the previous year.

1686. League of Augsburg entered into by Holland and other European powers for the purpose of causing the treaties of Münster and Nimeguen to be fulfilled on the part of France.

1689, May 12. The Grand Alliance signed at Vienna between England, the Emperor, and the States-General; to which Spain and the Duke of Savoy afterwards acceded.

1696, August 29. The Duke of Savoy quitted the coalition, and entered into a treaty with France.

1697, September 20. Peace of Ryswick, between France, England, Spain, and Holland; signed by Germany October 30.

1698, October 11. First Treaty of Partition signed between France, England, and Holland, for the purpose of regulating the succession of the territories of the King of Spain.

1699, January 26. Peace of Carlowitz, between Turkey and Germany, Poland, Russia, and Venice.

1700, March 13. Second Treaty of Partition between France, England, and Holland, declaring the Archduke Charles presumptive heir of the Spanish monarchy.

1701, September 7. England and Holland conclude a formal alliance at the Hague, to resist the claim of Philip of Anjou, to which almost all the European states successively accede.

1703. The Methuen Treaty, between England and Portugal, principally for the regulation of commerce.

1706, September 24. Peace of Alt Radstadt, between Charles XII. of Sweden and Augustus of Poland.

1711, July 2. Peace of Falczi concluded between Russia and Turkey, the Russians giving up Azof and all their possessions on the Black Sea to the Turks; in the following year the war was renewed, and terminated by the Peace of Constantinople, April 16, 1712.

1713, April 11. Peace of Utrecht, signed by the ministers of Great Britain and France, as well as of all the other allies, except the ministers of the empire. The most important stipulations of this treaty were the security of the Protestant succession in England, the disuniting the French and Spanish crowns, the destruction of Dunkirk, the enlargement of the British colonies and plantations in America, and a full satisfaction for the claims of the allies. Spain also granted to Great Britain the privilege of supplying Spanish America with negro slaves. This is the Assiento treaty.

1713, April 17. The Emperor Charles VI. published the Pragmatic Sanction, whereby, in default of male issue, his daughters should succeed in preference to the sons of his brother Joseph I.

1713, July 13. The Treaty of Utrecht signed by Spain, which included the Assiento contract.

1714, March 6. Peace of Radstadt, between France and the Emperor of Germany.

1714, September 7. Peace of Baden, between France and the Emperor of Germany. Landau ceded to France.

1715, November 15. The Barrier Treaty signed at Antwerp, by the British, the Imperial, and Dutch ministers. Low countries ceded to the Emperor of Germany.

1717, January 4. The Triple Alliance of the Hague, between France, England, and Holland, to oppose the designs of Cardinal Alberoni, the Spanish minister.

1718, July 21. Peace of Passarowitz, between the Emperor, Venice, and Turkey.

1718, August 2. The Treaty of Alliance between Great Britain, France, and the Emperor, signed at London. This alliance, on the accession of the states of Holland, obtained the name of the Quadruple Alliance, and was entered into to force the King of Spain to observe the stipulations of the treaty of Utrecht.

1718, November 18. The Duke of Savoy joined the Quadruple Alliance, signing the treaty by his envoys at Whitehall.

1719, November 20. Peace of Stockholm, between the King of

Great Britain and the Queen of Sweden, by which the former acquired the duchies of Bremen and Verden as Elector and Duke of Brunswick.

1720, January 26. The King of Spain accepts and signs the Quadruple Alliance.

1721, August 30. Peace of Nystett, in Finland, between Sweden and Russia, whereby Livonia and Ingria were ceded to Russia.

1724, March 24. Treaty of Stockholm, between Russia and Sweden, in favour of the Duke of Holstein Gottorp.

1725, April 30. The Vienna Treaty, signed between the Emperor of Germany and the King of Spain, by which they confirmed to each other such parts of the Spanish dominions as they were respectively possessed of.

1725, September 3. The Hanover Treaty concluded between the Kings of England, France, and Prussia, as an act of self-defence against the provisions of the Vienna Treaty.

1726, August 6. Treaty of Alliance between Russia and the Emperor of Germany.

1727, May 31. Preliminary articles for a general pacification, signed at Paris by the ministers of Great Britain, the Emperor of Germany, the King of France, and the States-General.

1727, October 21. Treaty of Nipchoo (Nerchinsk), between Russia and China, by which the boundaries of the two empires were settled, and a Russian resident at Pekin allowed. Not ratified until June 14, 1728, in consequence of the death of Catherine.

1729, November 9. The Peace of Seville, between Great Britain, France, and Spain: and a defensive alliance entered into: to this treaty the states of Holland afterwards acceded, November 21.

1731, March 16. The Treaty of Alliance of Vienna, between the Emperor of Germany, Great Britain, and Holland, by which the Pragmatic Sanction was guaranteed, and the disputes as to the Spanish succession terminated; Spain acceded to the treaty on the 22nd of July.

1732, October 7. Peace between Sweden and Poland.

1735, October 3. Preliminaries of peace signed at Vienna, between France and the Emperor of Germany. Spain acceded April 15, 1736.

1738, November 18. The Definitive Peace of Vienna, between the Emperor of Germany and the King of France, the latter power agreeing to guarantee the Pragmatic Sanction. Lorraine ceded to France, who acknowledged Augustus III. as King of Poland, abandoning the claim of Stanislaus, who resigned.

1739, September 18. Peace of Belgrade, between the Emperor of Germany and the Turks, the Emperor giving up Belgrade and Servia; this was speedily followed by a peace between Russia and Turkey, Russia surrendering Azof and all her conquests on the Black Sea.

1740, August. A Subsidy Treaty concluded between Great Britain and Hesse.

1741. Alliance between Great Britain, Russia, and Poland, with the Queen of Hungary (the Empress Maria Theresa), for the purpose of supporting the interests of the house of Austria; France, Spain, and Sardinia uniting about the same time in the interest of the Elector of Bavaria.

1742, June 28. Peace of Berlin, between the King of Poland and the Queen of Hungary. Silesia given up to Prussia.

1742, November 18. A Treaty for mutual defence and guarantee signed at Whitehall, between Great Britain and Prussia.

1743, June 24. A defensive Treaty concluded between Great Britain and Russia for fifteen years.

1743, August 7. Peace of Abo, between Russia and Sweden.

1745, April 23. Peace of Fuessen, between the Queen of Hungary and Elector of Bavaria.

1745, December 25. Peace of Dresden, between Saxony, Prussia, and the Queen of Hungary, confirming the treaties of Berlin and Breslau.

1748, April 30. Preliminary articles for the Peace of Aix-la-Chapelle signed by the ministers of Great Britain, France, and Holland, to which the Queen of Hungary, the King of Sardinia, and the Duke of Modena shortly after acceded, and Spain and Genoa before the end of June; in September and October the definitive treaty was concluded and signed by the respective powers. By this peace the treaties of Westphalia in 1648, of Nimeguen in 1678 and 1679, of Ryswick in 1697, of Utrecht in 1713, of Baden in 1714, of the Triple Alliance in 1717, of the Quadruple Alliance in 1718, and of Vienna in 1738, were renewed and confirmed; the Hanoverian succession in Great Britain recognised; the Pretender to be expelled from France, and Dunkirk to be demolished.

1750, October 5. Treaty between England and Spain, by which England renounced the Assiento Contract for the supply of slaves, included in the peace of Utrecht, in 1713.

1756, January 16. Treaty of Alliance between Prussia and England. Hanover put under the safeguard of the King of Prussia.

1756, May 1. Alliance between Austria and France concluded at Versailles.

1757, September 10. Convention of Closterseven.

1761, August 15. The Family Compact between the different branches of the House of Bourbon, signed at Paris.

1762, May 5. Peace of Petersburg, between Russia and Prussia. Russia restored all her conquests to Prussia.

1762, May 22. Peace of Hamburg, between Sweden and Prussia.

1762, November 3. Preliminaries of peace signed at Fontainebleau, between France and England.

1763, February 10. Peace of Paris concluded between France, Spain, Portugal, and Great Britain. Cession of Canada by France, and of Florida by Spain.

1763, February 15. Peace of Hubertsberg, between Prussia, Austria, and Saxony. End of the Seven Years' War.

1768, February 24. Treaty of Warsaw, between Russia and Poland.

1771, January 22. Treaty between Great Britain and Spain, confirming the possession of the Falkland Islands to the former.

1772, February 17. Secret Convention for the Partition of Poland by Russia and Prussia.

1772, August 5. Treaty of Petersburg for the same object, between Austria, Russia, and Prussia.

1774, July 21. Peace of Kutchuk Kainarji, between Russia and Turkey. Crimea declared independent, Azof ceded to Russia, and freedom of commerce and navigation of the Black Sea granted.

1775, May 20. The American Provinces sign Articles of Union and Alliance.

1778, February 6. A Treaty ratified with the States of America, by France, who acknowledged their independence.

1779, May 13. Peace of Teschen ratified between Austria, Saxony, and Prussia.

1780, July 9 and August 1. First Conventions for the Armed Neutrality, between Russia, Denmark, and Sweden. December 24, the States-General acceded.

1781, May 8. King of Prussia accedes to the Armed Neutrality.

1781, October 9. The Emperor of Germany joins the Armed Neutrality.

1782, November 30. The Independence of America acknowledged by England, and preliminaries of peace signed at Paris between the British and American Commissioners.

1783, January 20. Preliminary articles of peace signed at Versailles, between Great Britain, Spain, and France.

1783, September 2. Preliminaries of peace between Great Britain and Holland, signed at Paris.

1783, September 3. Definitive Treaty of Peace between Great Britain and the United States of America, signed at Paris; when the latter was admitted to be a sovereign and independent Power. On the same day, the definitive treaty was signed at Versailles between Great Britain, France, and Spain.

1784, June 20. Definitive Treaty of Peace between Great Britain and Holland, signed at Paris.

1785, July 23. Germanic Confederation between Saxony, Brandenburg, and Hanover.

1785, November 8. The Treaty of Fontainebleau, between the Emperor and Holland.

1790, September 27. The preliminary treaty ratified with Spain, relative to Nootka Sound; and the definitive treaty signed October 28th following.

1791, July 20. Convention of Pilnitz, between the Emperor Leopold and the King of Prussia.

1792, June 26. The First Coalition against France took place, and the King of Prussia issued his manifesto.

1793, February 9. The Duke of Tuscany acknowledged the French Republic.

1793, May 25. Spain engaged to assist Great Britain.

1793. Great Britain concluded treaties, July 14, with Prussia; August 30, with Austria; and September 26, with Portugal.

1795, February 15. The first Pacification between the National Assembly of France and the Vendeans, concluded.

1795, February 18. A defensive Alliance entered into with Russia, by Great Britain.

1795, April 5. Peace of Basel, between the King of Prussia and the French Republic.

1795, May 16. Treaty of Alliance signed at Paris, between France and the United Provinces, against England. Dutch Flanders ceded to France.

1795, July 22. Peace ratified at Basel between France and Spain. Spanish St. Domingo ceded to France.

1795, November 25. The Partition of Poland took place between Russia, Austria, and Prussia.

1796, May 15. Treaty of Paris, between the French Republic and the King of Sardinia, the latter ceding Savoy, Nice, the territory of Tende, and Beuil, and granting a free passage for troops through his states.

1796, August 5. The Treaty of Berlin ratified between Prussia and France, whereby the neutrality of the north of Germany was guaranteed.

1796, August 19. An Alliance offensive and defensive concluded at St. Ildefonso, between France and Spain.

1797, February 19. Treaty of Tolentino, between the French Republic and the Pope.

1797, April 18. Preliminaries of the Peace of Leoben signed between Austria and France.

1797, October 17. Treaty of Campo Formio, between France and Austria, the latter power yielding the Low Countries and the Ionian Islands to France; and Milan, Mantua, and Modena, to the Cisalpine republic.

1797, December 9. Congress of Radstadt commenced its labours to treat concerning a general peace with the Germanic powers.

1798, December 29. A Treaty of Alliance and Subsidies, agreed upon between Great Britain and Russia, against France.

1799, June 22. The Second Coalition against France, by Great Britain, the Emperors of Germany and Russia, part of the German empire, the Kings of Naples and Portugal, Turkey, and the Barbary States. Conference of Radstadt broken up.

1800, June 20. A Treaty of Subsidies ratified at Vienna, between Austria and England, stipulating that the war should be vigorously prosecuted against France, and that neither of the contracting powers should enter into a separate peace.

1800, September 30. A Treaty of Amity and Commerce ratified between France and the United States of America. Stipulated in the treaty that the flag should protect the cargo.

1800, December 16. A Treaty of Armed Neutrality ratified between Russia, Denmark, and Sweden, at Petersburg, in order to cause their flags to be respected by the belligerent powers. Prussia afterwards acceded to this treaty.

1801, February 9. Peace of Luneville, between the French Republic and the Emperor of Germany, confirming the cessions made by the treaty of Campo Formio, stipulating that the Rhine, to the Dutch territories, should form the boundary of France, and recognising the independence of the Batavian, Helvetic, Ligurian, and Cisalpine republics.

1801, March 21. A Treaty signed at Madrid, between France and Spain, whereby the estates of Parma were yielded to France, who in return ceded Tuscany to the Infanta Prince of Parma, with the title of King of Etruria.

1801, March 28. A Treaty of Peace between France and the King of Naples, signed at Florence, by which France acquired the isles of Elba, Piombino, and Presides.

1801, June 17. A Treaty concluded between Great Britain and Russia at Petersburg.

1801, July 15. The Concordat between Bonaparte and Pius VII., signed at Paris.

1801, August 8. A Treaty of Peace concluded between Spain and Portugal.

1801, September 29. A Treaty of Peace signed at Madrid, between France and Portugal.

1801, October 1. Preliminary articles of peace between France and England, signed at London by Lord Hawkesbury and M. Otto.

1801, October 8. A Treaty of Peace ratified at Paris between the Emperor of Russia and the French government.

1802, March 25. Peace of Amiens, between Great Britain, France, Spain, and Holland.

1802, June 25. Definitive Treaty between France and the Ottoman Porte.

1803, August 1. A Treaty ratified between Great Britain and Sweden.

1805, April. 8. The Treaty of Petersburg entered into for a Third Coalition against France; England and Russia being the contracting parties.

1805, August 9. The Emperor of Austria acceded to the Treaty of Petersburg.

1805, August 31. An Alliance offensive and defensive entered into at Beekaskog, between Great Britain and Sweden.

1805, September 8. Third Coalition against France, the parties being Great Britain, Russia, Austria, Sweden, and Naples.

1805, September 21. A Treaty of Neutrality signed between France and Naples.

1805, December 26. Peace of Presburg, between France and Austria, by which the ancient states of Venice were ceded to Italy; the principality of Eichstett, part of the bishopric of Passau, the city of Augsburg, the Tyrol, all the possessions of Austria in Suabia, in Brisgau, and Ortenau, were transferred to the Elector of Bavaria and the Duke of Wirtemberg, who, as well as the Duke of Baden, were then created kings by Napoleon; the independence of the Helvetic Republic was also stipulated.

1806, July 12. The Germanic Confederation of the Rhine formed under the auspices of Napoleon.

1806, July 20. Peace of Paris, between France and Russia, which Alexander subsequently refused to ratify.

1806, August 1. The Treaty of July 12 notified to the Diet at Ratisbon, when the German princes seceded from the Germanic empire, and placed themselves under the protection of Napoleon.

1806, October 6. The Fourth Coalition formed against France, by Great Britain, Russia, Prussia, and Saxony.

1806, November 21. The Berlin Decree, issued by Bonaparte after the battle of Jena, declaring the British Islands in a state of blockade, and interdicting the whole world from any communication with them.

1806, December 11. A Treaty of Peace and Alliance signed at Cosen, between Napoleon and the Elector of Saxony, who then assumed the title of king.

1806, December 31. A Treaty of Commerce entered into between Great Britain and the United States of North America, which the latter Power afterwards refused to ratify.

1807, July 7. Peace of Tilsit concluded between France and Russia, when Napoleon restored to the Prussian monarch one-half of his territories, and Russia recognised the Confederation of the Rhine, and the elevation of Napoleon's three brothers, Joseph, Louis, and Jerome, to the thrones of Naples, Holland, and Westphalia; this treaty was ratified on the 19th.

1807, October 31. A Treaty of Alliance entered into between France and Denmark.

1807, November 10. A Treaty ratified at Paris between France and Holland, whereby Flushing was ceded to the French.

1807, December 17. Milan Decree issued by Napoleon; England declared in a state of blockade.

1808, February 8. Treaty of Peace between Great Britain and Sweden.

1808, March 30. A Treaty of Alliance and Subsidy entered into between England and Sicily, whereby the latter was to be garrisoned by 10,000 British troops, and to receive an annual subsidy of 300,000*l.*

1808, May 5. Treaty of Bayonne, whereby Charles IV. ceded all his titles to Spain and its dependencies to Napoleon, expressly resigning to him the right of transmitting the crown to whomsoever he should think fitting.

1808, June 25. A Spanish Proclamation of Peace with England, and Sweden, her ally, published at Oviedo.

1808, August 30. The Convention of Cintra signed, the French agreeing to evacuate Portugal.

1808, November 5. The Convention of Berlin entered into, whereby Napoleon remitted to Prussia the sum due on the war-debt, and withdrew his troops from many of the fortresses in order to reinforce his armies in Spain.

1809, January 5. Peace ratified between Great Britain and the Ottoman Porte.

1809, January 14. A Treaty of Alliance ratified between England and the Spanish insurgents.

1809, April 9. The Fifth Coalition against France, by Great Britain and Austria.

1809, July 25. Armistice between Sweden and Norway.

1809, September 17. A Treaty of Peace signed between Russia and Sweden.

1809, October 14. Peace of Vienna, between France and Austria; Austria ceding to France the Tyrol, Dalmatia, and other territories, which were shortly afterwards declared to be united to France under the title of the Illyrian provinces, and engaging to adhere to the prohibitory system adopted towards England by France and Russia.

1810, January 6. Peace of Paris, between France and Sweden, whereby Swedish Pomerania and the island of Rugen were given up to the Swedes, who agreed to adopt the French prohibitory system against Great Britain.

1810, February 19. Treaties of Alliance and Commerce signed between Great Britain and the Brazils.

1810, April 19. The South American provinces of Caraccas, &c., form a federative government, under the title of the Federation of Venezuela.

1812, March 14. Treaty of Alliance signed at Paris between France and Austria.

1812, March 24. Treaty of Alliance, signed at St. Petersburg, between Bernadotte, Prince Royal of Sweden, and the Emperor Alexander; the former agreeing to join in the campaign against France, in return for which Sweden was to receive Norway.

1812, April 1. The Berlin Decree revoked as far as respected America.

1812, May 28. Preliminaries of peace ratified at Bucharest between Russia and Turkey, it being stipulated that the Pruth should form the limits of those empires.

1812, July 6. A Treaty of Peace between Great Britain and Sweden ratified at Orebo.

1812, July 20. Treaty signed between the Emperor Alexander and the Regency of Cadiz, in the name of Ferdinand the Seventh of Spain.

1812, August 1. Treaty of Peace and Union ratified at St. Petersburg between Great Britain and Russia, renewing their ancient relations of friendship and commerce.

1813, January 25. Concordat at Fontainebleau, between Napoleon and Pius VII.

1813, March 1. The Sixth Coalition entered into between Russia and Prussia against France, the treaty being ratified at Kalisch.

1813, March 3. The Treaty of Stockholm entered into between England and Sweden.

1813, June 14. A Treaty of Alliance concluded between Great Britain, Russia, and Prussia.

1813, July 8. The Convention of Peterswalden, between Great Britain and Russia.

1813, July 10. A reciprocal Treaty of Alliance and Guarantee between France and Denmark, ratified at Copenhagen.

1813, September 9. A Triple Treaty of Alliance ratified at Toplitz between Russia, Austria, and Prussia.

1813, October 3. A preliminary Treaty of Alliance signed at Toplitz between Austria and Great Britain.

1813, December 8. Treaty of Valençay, between Napoleon and Ferdinand the Seventh of Spain, whereby the latter was to be put in full possession of that kingdom, on agreeing to maintain its integrity.

1814, January 14. Treaty of Kiel, between Great Britain, Sweden, and Denmark. Norway ceded to Sweden.

1814, February 5. The Cortes of Spain renounce the treaty ratified at Valençay.

1814, February 5. Congress of Chatillon, between the four great powers allied against France, at which Caulaincourt attended on the part of France; the Congress broke up on the 19th of March.

1814, March 1. Treaty of Chaumont, between Great Britain, Austria, Russia, and Prussia.

1814, April 11. The Treaty of Paris ratified on the part of Napoleon and the Allies, by which Napoleon renounced his sovereignty over France, &c., stipulating that the island of Elba should be his domain and residence for life, with a suitable provision for himself and Maria Louisa, who was to have vested in her the duchies of Parma and Placentia, the same to descend to her son.

1814, April 23. A Convention signed at Paris between the Count d'Artois on the one part, and the Allied Powers on the other, stipulating that all hostilities should cease by land and sea; that the confederated armies should evacuate the French territory, leaving its boundaries the same as they were on the 1st of January, 1792.

1814, May 30. Peace of Paris ratified between France and the Allied Powers, in a supplemental article of which Louis XVIII. stipulated that he would exert his endeavours with the continental powers to ensure the abolition of the slave-trade, in conjunction with Great Britain.

1814, July 20. A Treaty of Peace signed between France and Spain at Paris, confirming the stipulations of previous treaties which had existed on the 1st of January, 1792.

1814, August 13. Convention between Great Britain and the Sovereign Prince of the Low Countries respecting the Dutch colonies.

1814, September 28. A Convention ratified at Vienna, whereby Saxony was placed under the control of Prussia.

1814, December 24. Peace of Ghent, between Great Britain and the United States of America.

1815, March 23. Treaty of Vienna, between Great Britain, Austria, Russia, and Prussia, confirming the principles of the treaty of Chaumont, March 1, 1814, on which they had acted; and uniting Belgium to the Netherlands under the sovereignty of the king of the Netherlands.

1815, May 18. Peace ratified between Saxony and Prussia.

1815, May 20. A Convention signed at Zurich between the Swiss Diet and the plenipotentiaries of Great Britain, Austria, Russia, and Prussia.

1815, May 31. Treaty of Vienna, between the King of the Low Countries on the one part, and Great Britain, Russia, Austria, and Prussia on the other, agreeing to the enlargement of the Dutch territories, and vesting the sovereignty in the House of Orange.

1815, June 4. Treaty of Vienna. Denmark cedes Swedish Pomerania and Rugen to Prussia, in exchange for Lauenburg.

1815, June 8. Federative Constitution of Germany signed at Vienna.

1815, July 3. Convention of St. Cloud, between Marshal Davoust on the one part, and Wellington and Blücher on the other, by which Paris was surrendered to the Allies, who entered it on the 6th.

1815, August 2. A Convention signed at Paris between Great Britain, Austria, Russia, and Prussia, styling Napoleon the prisoner of those powers, and confiding his safeguard particularly to the British government.

1815, September 14. A Convention entered into at Vienna, whereby the duchies of Parma, &c., were secured to the Empress Maria Louisa, and on her demise to her son, by Napoleon.

1815, September 26. The Treaty denominated of the Holy Alliance, ratified at Paris by the Emperors of Austria and Russia, and the King of Prussia.

1815, November 5. A Treaty ratified at Paris between Great Britain and Russia respecting the Ionian Islands, which were declared to form a united state under the sole protection of the former power.

1815, November 20. Peace of Paris, between France on the one part, and Great Britain, Austria, Russia, and Prussia on the other, establishing the boundaries of France, and stipulating for the garrisoning of several of the fortresses in France by foreign troops for three years.

1815, November 20. The Treaty of Paris executed between Great Britain, Russia, Austria, and Prussia, confirming the treaties of Chaumont as well as those of Vienna.

1816, March 13. A Treaty entered into between France and the Swiss Cantons, whereby 12,000 Swiss troops were admitted into the French service.

1817, June 10. Treaty of Paris, between Great Britain, France, Spain, Russia, and Prussia, in order to fulfil the articles of the Congress of Vienna.

1818, April 25. A Convention signed at Paris between France and the Allied Powers, releasing France from all debts referred to in the treaties from the 30th May, 1814, to the 20th November, 1815.

1818, April 25. A Convention ratified at Paris between England and France, whereby the latter power undertook to liquidate all further demands on the part of British subjects.

1818, May 4. A Treaty ratified between Great Britain and the Netherlands for abolishing the slave-trade.

1818, October 9. A Convention entered into by the great powers of Europe, assembled at Aix-la-Chapelle, on the one part, and the Duke de Richelieu on the other, whereby it was stipulated that the army of occupation should quit the French territory on the 30th of November ensuing; it was also agreed that the remaining sum due from France to the Allies was 265,000,000 francs.

1819, August 1. Congress of Carlsbad.

1820, October 20. Congress of Troppau.

1820, October 24. Treaty between Spain and America: Florida ceded to the United States.

1821, May 6. The Congress of Laybach, which had been for some time attended by the sovereigns of Austria, Russia, and Prussia, finally broke up, having issued two circulars stating it to be their resolution to occupy Naples with Austrian troops, and proscribe popular insurrection.

1822, August 25. Congress of Verona.

1824, February 4. A Convention between Great Britain and Austria laid upon the table of the House of Commons, by which the former agreed to accept 2,500,000*l*. as a final compensation for her claims upon the latter power, amounting to 30,000,000*l*.

1824, June 16. Commercial Treaty between Great Britain and Denmark.

1825, February 2. Treaty of Commerce signed at Buenos Ayres between Great Britain and the United Province of Rio de la Plata.

1825, February 28. Convention between Great Britain and Russia; frontier of north-west coast of America settled.

1825, April 17. France recognises the independence of St. Domingo.

1825, April 18. Treaty of Amity between Great Britain and Columbia.

1825, September 20. Commercial Treaty between Great Britain and Hanse Towns.

1825, October 18. Treaty between Great Britain and Brazil for abolition of slave-trade.

1826, January 26. Treaty of Navigation between Great Britain and France.

1826, May 19. Treaty of Navigation between Great Britain and Sweden.

1826, September 4. Treaty of Akermann, between Russia and Turkey, respecting the Principalities of Moldavia and Wallachia.

1826, November 13. Convention concluded between Great Britain and the United States, concerning indemnities to American subjects injured by the war.

1828, February 22. Peace of Turkmanchay, between Russia and Persia. Erivan and the country to the Araxes ceded to Russia.

1828, June 26. Convention between Great Britain and Spain for satisfying claims of British merchants.

1828, August 29. Treaty of Peace between Brazil and Buenos Ayres, at Rio Janeiro.

1828, October 28. Peace between Naples and Tripoli.

1829, July 6. Treaty of London, between Russia, France, and Great Britain, for the settlement of the affairs of Greece.

1829, September 14. Peace of Adrianople, between Russia and Turkey, by which Russia acquires the protectorate of Moldavia and Wallachia.

1830, May 7. Treaty between Turkey and the United States. American vessels allowed to pass to and from the Black Sea.

1830, November 2. The independence of Belgium recognised by England and France.

1831. The commercial union of the northern states of Germany, known as the Zollverein, commenced under the auspices of Prussia.

1831, November 15. A Treaty signed between Great Britain and France, for a settlement of the points of dispute between Holland and Belgium, to which Holland acceded March 13, 1838.

1833, July 8. Treaty at Constantinople between Turkey and Russia, by which it was stipulated that the Dardanelles should be shut to all foreign vessels of war.

1834, April 22. Quadruple Treaty between Great Britain, France Spain, and Portugal, in support of the two queens, Isabella and Maria.

1835. Supplementary Treaties with Portugal and Spain, by the former of which the Methuen Treaty with Portugal was annulled.

1837, November 16. Treaty at the Hague with Holland, by which discriminatory duties on the ships and cargoes of Great Britain and Holland are respectively abolished.

1838, July 3. A Commercial Treaty between Great Britain and Austria, signed at Vienna.

1838, November 16. A Commercial Treaty concluded in London between Turkey and Great Britain.

1840, July 15. Treaty signed in London between Great Britain, France, Austria, Russia, Prussia, and Turkey, for the settlement of the dispute between Turkey and Mehemet Ali.

1841, June 15. Treaty between Great Britain and Denmark relative to the passage of the Sound.

1841, July 13. Convention at London, between the European Powers and Turkey, by which the closing of the Dardanelles against ships of war is made general to them all while Turkey is at peace.

1842, August 29. Treaty of Nankin with China, by which several ports were opened to the British trade, Hong-Kong ceded, and an indemnification of 21,000,000 dollars paid.

1844, July 22. Treaty between Great Britain and Hanover for the regulation of the Stade Duties.

1844, September 2. Treaty between Belgium and the German States parties to the Zollverein.

1845, May 29. A Convention signed in London between Great Britain and France for the suppression of the Slave Trade.

1845, June 25. Treaty of Commerce for ten years ratified between Great Britain and the Two Sicilies.

1846, November 16. Austria, Russia, and Prussia revoke the treaty of 1815, constituting Cracow a free republic, and restore the territory to Austria. Soon after the kingdom of Poland is incorporated with Russia. Great Britain, France, Sweden, and Turkey unite in a protest against these proceedings.

1849, August 6. Treaty of Milan, between Austria and Sardinia.

1850, February 27. Treaty at Munich between Austria, Bavaria, Saxony, and Würtemberg, to form a Southern German Union against the pretensions of Prussia.

1850, April 19. Treaty at Washington between Great Britain and the United States, respecting a ship-canal through the state of Nicaragua, to connect the Atlantic and Pacific Oceans.

1850, July 2. Treaty of Peace between Prussia and Denmark, Prussia withdrawing from the support of the duchies of Holstein and Schleswig; and on July 4 a protocol was signed in London between Great Britain, France, Prussia, and Sweden, guaranteeing the integrity of the Danish territories.

1852, April 6. Coalition at Darmstadt between Saxony, Bavaria, Würtemberg, Baden, Nassau, and the two Hesses, against the renewal of the Zollverein, except Austria be admitted into the Union.

1853, February 18. Treaty at Washington between Great Britain and the United States, for an international copyright.

1853 February 19. Commercial Treaty signed at Berlin between Austria and Prussia, for twelve years.

1853, December 3. Protocol signed at Vienna by Great Britain, France, Austria, and Prussia, for the maintenance of the integrity of the Ottoman empire, and for the restoration of peace between her and Russia.

1854, March 12. Alliance of Constantinople, between Great Britain, France, and Turkey, against the hostilities of Russia.

1854, April 20. Treaty of Berlin, between Austria and Prussia, for the mutual defence of their respective territories, and of Germany; and against Russia, should that power cross the Balkan.

1854, June 7. Treaty at Washington between the United States and Canada, by which the British-American coast-fisheries are thrown open to the United States fishermen, the navigation of the St. Lawrence and the Canadian lakes declared free, and the products of the two countries (except sugar and tobacco) reciprocally exempted from duty.

1854, December 2. Treaty of Alliance signed at Vienna between Great Britain, France, and Austria.

1855, January 10. Sardinia joins the Alliance of Great Britain and France against Russia, agreeing to send a contingent force to the Crimea.

1855, November 9. An international copyright treaty concluded with Prussia.

1856, February 1. Protocol signed at Paris by the plenipotentiaries of Russia, and those of Great Britain, France, Austria, and Turkey, for a peace between those powers.

1857, March 3. Treaty of Peace signed at Paris between Great Britain and Persia.

1857, March 14. Treaty between Denmark and the principal states of Europe, for the abolition of the Sound dues; signed at Copenhagen.

1857, May 26. Treaty signed at Paris by the great European Powers, for the settlement of the dispute between Prussia and Switzerland relative to Neufchâtel.

1858, June 26. Treaty of Tien-tsin with China, by which intercourse with the interior of China was stipulated for, several additional ports were opened to British commerce, and a British ambassador admitted to reside at Pekin.

1858, August 20. Convention signed at Paris, constituting Moldavia and Wallachia independent principalities, under the suzerainty of Turkey.

1858, August 26. Commercial Treaty between Great Britain and Japan, signed at Jeddo.

1860, February 11. Commercial Treaty between Great Britain and France, published in the 'Moniteur.'

1860, March 24. Treaty between France and Sardinia, signed at Turin, by which Savoy and Nice are ceded to France.

1860, July 11. Peace of Villa Franca, between France and Austria, by which Lombardy is transferred to Sardinia, and a confederation of Italian States, under the protection of Austria, stipulated for. This treaty was formally ratified at Zurich on Nov. 11.

1860, October 24. Ratification of the Treaty of Tion-tsin, and a new peace with China, signed at Pekin; China paying an indemnity for the expenses of the allies and the losses of the British merchants.

1861, May 1. Commercial Treaty between France and Belgium.

1861, May 15. Commercial Treaty between Great Britain and Turkey, signed at Constantinople.

There are several voluminous collections of treaties, of which one of the most complete is that of G. F. von Martens, who continued the works of Du Mont and Rousset, of which the first volume was published in 1790. A preliminary account of all preceding printed collections was published by him in 1802. Successive supplements, by different editors, have brought down the account of the various treaties to a very recent period. The collection of C. W. Koch, in 15 vols. 8vo, is a useful one, but does not come down so late.

TREES, LAWS RELATING TO. [Timber.]

TRENCH, in military works, is an excavation in the ground from twelve to eighteen feet wide, and three feet deep, and generally of considerable length, the earth being thrown up on one side in order to form a sort of parapet by which the soldiers in the trench may be covered from the view, or protected from the fire of the enemy. [Sap; Siege.]

TRENT, COUNCIL OF (*Concilium Tridentinum*), was first convoked by a bull of Pope Paul III., dated May, 1542, but the war between the Emperor Charles V. and Francis I. of France, together with the negotiations then being carried on between the emperor and the German princes who had embraced the Protestant faith, prevented its installation until December 13, 1545: even then only four archbishops, twenty bishops, five heads of monastic orders, three papal legates, and an auditor, besides the imperial orators or envoys, were present; but other prelates afterwards gradually joined the assembly. After arranging some preliminary difficulties, the council proceeded to consider the two great objects for which it had been convoked—the definition of the dogmas of faith and the condemnation of heresies, and the reform of the church in matters of discipline and jurisdiction. The German bishops, supported by the envoys of the emperor, urged that the labours of the council should begin with the business of reform, as it was the relaxation of discipline that had first occasioned the present schism in the church, and that the only chance of reclaiming the seceders was to manifest an earnest will to reform abuses before proceeding to condemn them and their tenets; that if the council did not take in hand speedily the work of church reform, the lay powers would take it up themselves, to the manifest injury of the ecclesiastical authority. The bishop prince of Trent spoke at length on this side, as, being on the threshold of Germany, he was acquainted with the state of opinions in that country; and the majority of the prelates seemed to incline to his opinion. The papal legates, however, supported by the Italian prelates, were of opinion that the council should begin with defining the dogmas, as that was the highest task, and ought to be first attended to, because faith is the foundation of all moral virtues; that the outcry about reform was well known to be mainly directed against the court of Rome and its jurisdiction, and was an indirect attack upon the authority of the sovereign pontiff, towards whom it would be more reverent to leave him the initiative in correcting the abuses of his own court, while the council was attending to the graver questions of religion, otherwise dissensions would arise between the head and body of the church, only to the advantage and satisfaction of heretics. At last, in order to conciliate all parties, it was resolved that the two departments of doctrine and discipline should be proceeded with simultaneously; that for every sitting congregation engaged in discussions on dogma, there should be another concerning the reform of discipline; and this resolution was at last agreed to by the pope.

The council, at the beginning of its regular session, undertook to define first of all what were the sources of authority in matters of faith. It declared that the Catholic doctrines are contained in the authentic books of the Old and New Testaments, and also in the traditions concerning faith and morals which are preserved in the Catholic Church. This was a condemnation of Luther's assertion that all the doctrine of the Christian faith is contained in the Scriptures, and that unwritten tradition is not to be held as authority.

The council next proceeded to define the dogmas of faith, such as those of original sin, predestination, grace, and free will, the definition of which may be seen in the catechism published by the name of 'Catechismus ad Parochos,' or 'Catechism of the Council of Trent,' which is translated into most languages.

The council next propounded the doctrine of the church concerning the sacraments, which they stated to be seven in number, namely, baptism, confirmation, the eucharist, confession or penitence, extreme unction, ordination, and matrimony; and afterwards they proceeded to treat of each of them seriatim, laying down the orthodox doctrine and anathematising the discordant tenets of the Lutherans, Zwinglians, and other heretics. At the same time the council proceeded with discussions on subjects of discipline and reform. The question of pluralities proved a most difficult one to settle. The Spanish bishops made a strong remonstrance against the abuses of pluralities and non-residence, and wished the council to pass at once severe decrees against both. The legates proposed that the pope should take into his own hands the task of reform, and they wrote to Rome accordingly, and the pope directed a bull to the council by which he referred the matter to himself. This bull met with great opposition, and was a source of misunderstanding between Rome and the council. At last, in March, 1547, the legates suddenly closed the session, which was reckoned the seventh since the opening of the council, and in virtue of the authority they held from the pope they transferred the council to Bologna, under the plea that a contagious disorder had broken out in the city of Trent. The majority of the prelates assented; but there were eighteen bishops, chiefly of the dominions of the emperor, who refused to leave Trent. The others followed the legates to Bologna, where, after opening the session, the council was adjourned *sine die*. Charles V. protested against the meeting of Bologna, which he did not acknowledge as a council, and insisted upon the council being restored to Trent.

In 1549 Pope Paul III. died, and his successor Julius III. again convoked the council at Trent, in May, 1551. Not many prelates attended. The council of Trent proceeded to define the doctrine of transubstantiation, the Lord's Supper, and the mass, and afterwards that of confession and the other sacraments. At the same time decrees were made concerning points of discipline, touching the episcopal jurisdiction, the appeals to Rome, and other such matters. In 1552 the pope prorogued the council, and this prorogation was continued for ten years, during which period three popes died in succession,—Julius III., Marcellus II., and Paul IV. At last Pius IV. being elected, began to think seriously of re-opening the general council, of which the church seemed to stand more in need than ever.

In 1561 the Fathers gathered again at Trent, and on the 18th of January, 1562, the session was solemnly opened. One hundred and twelve, consisting of archbishops, bishops, and mitred abbots, were present, besides the cardinals. The orators of the various states were also present. After very lengthened discussions on various subjects, and some interruptions from political causes, the council, in July, 1563, issued its canon on the subject of residence. Without entering into the question of divine right, it enjoined all bishops, archbishops, and cardinals having the charge of a see or cathedral church, to reside personally in their respective cathedrals throughout the year, and more especially during the Lent, Advent, Christmas, Easter, and other solemn festivals, except in cases of urgent necessity, through motives of Christian charity, or "for the evident advantage of the church or commonwealth," and then not without the written approbation of the pope or of the metropolitan. The same decree was extended to incumbents of parishes.

The council issued a canon concerning the doctrine of the institution of bishops. It stated that there is a hierarchy in the church, instituted by divine ordination, and consisting of bishops and presbyters and other ministers; that bishops are superior to presbyters, and have the power of ordaining and confirming, which is not given to the others; that the only legitimate bishops are those ordained by the pope or by other ecclesiastical and canonical authority.

The council next laid down the doctrine of the Catholic Church concerning marriage, which it reckons as one of the sacraments. Among other articles on this subject, it condemns polygamy as contrary to divine law; it forbids persons in holy orders contracting marriage; and it states marriage to be indissoluble, even after the adultery of one or both of the parties.

On the important question of clandestine marriages,—that is to say, marriages contracted before witnesses without the intervention of the parish priest,—the council decreed that in future no marriage should be considered valid which was not contracted before the parish incumbent or before another clergyman duly deputed by the incumbent, or by the ordinary, and in presence of at least two witnesses besides, and that their names, as well as the names of the married parties, and the date of the celebration of the marriage, should be entered into a register to be kept by every parish incumbent. The council explained also what were the cases of relationship and other canonical impediments to the contracting of marriages; and although it did not condemn altogether the practice of dispensations being granted by the pope in particular instances, it recommended that such dispensations should be granted rarely, gratuitously, and on proper and sufficient grounds.

Hitherto the secular princes had insisted upon reforms of the church and clergy; now the pope and court of Rome urged the council to make reforms affecting the princes and their courts. According to instructions received from Cardinal Borromeo, the pope's minister at Rome, the legates laid before the assembly several motions, chiefly in support of the ecclesiastical immunities. The following were among the principal heads:—That churchmen should not be summoned before the lay courts. That the lay courts and magistrates should not interfere in cases of matrimony, heresy, tithes, patronage, patrimonial benefices, ecclesiastical fiefs, the temporal jurisdiction of churches, nor in any cause, civil, criminal, or mixed, pertaining to the ecclesiastical courts. That churchmen should not be liable to pay taxes, tenths, forage, or subsidies of any sort, either on the property of the church or on their own patrimonial property. That the property of the church, moveable and immoveable, of every sort, tithes and other rights, should be held as sacred from the hands of the lay powers. That all letters, citations, sentences, and excommunications, from the ecclesiastical courts, or from Rome, should be promulgated and executed without requiring any exequatur or permission from the civil power. That neither emperor nor king, nor any other prince, should interfere with the said courts or with the tribunal of the Inquisition, but should, when required, give them the assistance of the secular arm.

The above demands put forth by the legates raised a storm on the head of the council. The Emperor Ferdinand and Charles IX. of France protested against any such proceedings, and the pope directed his legates to withdraw the obnoxious motions, and to content themselves with a general admonition to all Christian princes, which was adopted by the council, exhorting them to respect and cause to be respected the rights and immunities of the church, and the constitutions of the popes and councils in favour of ecclesiastical persons and ecclesiastical liberties. But the obnoxious principles started by the legates of Pius IV. were revived by his successor Pius V., and promulgated by him in the famous bull "In Cœna Domini."

The council now drew to its conclusion. A number of canons concerning doctrine as well as discipline were passed; other minor points were referred to the decision of the pope. The doctrine of purgatory and indulgences, and of the benefit derived to the departed souls from the prayers of the living, were confirmed. The invocation of the saints who intercede with God on behalf of men, and the veneration for their relics, were likewise adopted. The images of Christ and the saints were to be retained and venerated in the churches for the sake of those whom they represent, at the same time that no meretricious ornament or other sensual enticement was to be mixed with the devotional practices. Severe penalties were decreed against churchmen having concubines, against simony, against pluralists of livings with cure of souls, and against duellists. Several regulations were made for the proper examination and selection of candidates to vacant sees, or to livings with cure of souls. The bishops were enjoined to make a visitation of their dioceses once every year with a modest train and retinue, and they, as well as the parish incumbent, to preach every Sunday and other solemn festivals. No one was to be appointed to a benefice with cure of souls under twenty-five years of age. Criminal charges against a bishop to be judged by the Roman pontiff. Provincial synods to meet once every three years, and diocesan synods every year.

These and other canons being passed, in the beginning of December, 1563, it was agreed that the council should be closed. The acts of the council were then authenticated by the notaries, and by the secretary of the council, and signed by the fathers to the number of 255, namely, 4 legates and 2 other cardinals, 3 patriarchs, 25 archbishops, 168 bishops, present; 39 proxies, 7 abbots and 7 generals of monastic orders. The acceptation of the ambassadors was then requested and given, except the ambassador of Philip of Spain, who by order of his king opposed the closing of the council, and the ambassadors of France, who had left Trent in dudgeon.

Pope Pius IV., in solemn consistory, on the 26th of January, 1564, confirmed the acts of the council by a bull countersigned by the cardinals. All the Roman Catholic states accepted the council, and promulgated it in their states, with the exception of France, which persisted in those assertions of jurisdictional independence of its church and king, which were afterwards embodied in a regular form by the assembled French clergy in 1682.

Two distinguished Roman Catholic writers have written professedly the history of the council of Trent, its proceedings and acts: one, the famous Frà Paolo Sarpi, displays at times a feeling hostile to the court of Rome; the other, Cardinal Sforza Pallavicino, on the contrary, writes in a tone of perfect submission to the Roman see. By comparing the two works, readers are enabled to come to something like a fair understanding of the labours and the merits of that memorable assembly.

TREPAN. [Trephine.]

TREPHINE is a kind of saw employed in surgery for the removal of a circular portion of bone. For this purpose it is used in various cases, such as diseases requiring perforation of the antrum, necrosis with loose enclosed sequestra, abscesses in bone or under bones, &c.; but especially in injuries of the head and their various consequences, for which the removal of a portion of the skull is deemed necessary.

The trephine is now commonly employed in this country instead of a somewhat similar instrument, the trepan, which was formerly used by all surgeons, and is still frequently used on the Continent. The trepan is very like the tool called a wimble, which is used by coopers for boring holes for large corks, and is worked in the same way, with a curved rotating lever under the handle; but instead of the share-like cutting edge of the wimble, the trepan has a circular saw, which, being rotated with the lever, cuts its way through the bone.

The trephine is a smaller and more simple, but, in other respects, not more convenient instrument. Its handle is like that of a gimlet, but stronger. The shaft is terminated below by a sharp steel point, called the centre-pin, which may be fixed and removed at pleasure, and which stands in the centre of the circle formed by the saw. The purpose of the centre-pin, which projects a little below the edge of the saw, is to fix the trephine before the working of the saw; and it is kept in its place till the saw has cut a groove sufficiently deep to steady it in its further working. After this the centre-pin should be removed, for it hinders the action of the saw, and (in trephining the skull) would perforate the dura mater before the saw had cut through the bone. Around the handle of the trephine, at a short distance above the part to which the centre-pin is fixed, there is attached a hollow steel cylinder, the lower margin of which is a saw. This is called the crown of the trephine, and, for various purposes is of different sizes.

In using the trephine, the saw is made to cut through the bone, not by a series of complete rotations, such as are made by the trepan, but by rapid half-rotations alternately to the right and to the left, as in boring with an awl. In trephining the skull various cautions are necessary, according to the form of the bone to be cut through, and the nature of the parts immediately beneath it; but the most comprehensive rule is to examine frequently what progress the saw makes, and, if it have cut through one part of the circle much sooner than the rest, to apply it somewhat obliquely, taking off the pressure of its edge from that part. The most dangerous part of the operation is when the bone is nearly cut through; for it is necessary to avoid wounding the dura mater, injuries of which are often followed by severe disease. To escape these, it is advisable when a part of the circle is cut through, and but a thin plate of bone remains in the rest of its extent, to break through this by an elevator or proper forceps. And if, after using either of these instruments, sharp points of bone are left projecting from the margin of the circular aperture, these must be carefully cut or broken off.

The use of the trephine is now much more rarely required than in former times; and this, not only because, since the time of Mr. Pott, surgeons have learned that it is beneficial in few injuries of the head beyond those in which there are distinct signs of compression of the brain, but also because, in many of the cases in which it is necessary to remove portions of bone, the instrument called Hey's saw is far more convenient. This consists of a handle and a shaft, much like those of a common fork, of which the latter has fixed to its end a transverse broad plate of steel, one end of which is a straight, the other a convex saw. With this, portions of bone of almost any form and size can be cut out both more easily and more rapidly than is possible with the trephine. It is especially useful in those cases of fracture of the skull in which angles of the broken bone are depressed, and for which the trephine used to be applied chiefly for the purpose of introducing the elevator; for in these the depressed portion itself may be cut off, and the elevator may, if necessary, be introduced at the aperture which is thus made.

TRESPASS is a wrong directly done to the person, to the goods and chattels, or to the lands and tenements of any man.

To the person it may be by menace, assault, battery, or maiming. [Assault.] To either dead or live chattels, by taking them away or by injuring them. To land and tenements, by entering upon them and injuring them. Trespass is the action by which a person in the actual and exclusive possession of property is protected against the forcible interference with it by those who are not entitled to it. By this action also he may recover damages for the injury done to his possessions.

To constitute trespass, the act done must be wilful, not the result of negligence, and have something of force in it, so as to be, according to the construction of the law, against the peace; and the injury must be the immediate, not the consequential result of the act. This is rendered very intelligible by the instance given (1 Strange, 636): "If a man throw a log into the highway, and in that act it hits me, I may maintain trespass, because it is an immediate wrong; but if, as it lies there, I tumble over it, and receive an injury, I must bring an action on the case." But it is not necessary that it should be done with the design to cause the injury complained of, it may be done in mistake or ignorance. Thus where one shooting at a mark hits a bystander, he is guilty of trespass. A sheriff commits an act of trespass if he takes the goods or arrests the person of B, mistaking him for A. A man is liable in trespass for the injury done by his cattle to the land of another, whether he knew of their doing it or not. In trespass, all persons who assist in the act done, or cause it to be done, or, if it is for their use, assent to it afterwards, are considered as principals, although not actually present at the doing of the act. Where an act is done by a servant while in the discharge of his business as servant, the master is liable for the act in trespass. But if it be wilful on the part of the servant, and not in discharge of his master's business, the master is not liable.

Where a person has an authority or licence given him *by law*, and he takes advantage of that to commit an act of trespass, he is held to have been a trespasser from the very commencement of the proceedings: as where a landlord lawfully distrains a beast and afterwards works or kills it, or an officer of the customs entitled to search "unpacks stuffs and puts them in the dirt." If, however, the licence or authority has proceeded from a private party, the trespass does not relate back, but is confined to the mere act itself: as where parties enter a tavern, drink and pay for wine, and afterwards commit a trespass—that will not make their entry a trespass. In cases where a trust is reposed, trespass will lie for an act which is at variance with the trust, as where a lessee at will cuts down the timber.

Various circumstances may exist which afford a justification for an act which otherwise would amount to trespass. Thus a man is not liable in trespass though his cattle have entered the field of another, if they have done so in consequence of the neglect of the party into whose lands they enter to repair the fences between the lands of the parties; though it is no justification that the cattle have entered because the land was open to the highway. Again, a man is justified in entering upon the lands of another to retake his goods which have been carried there by the occupier of those lands; or to carry away goods bought of the occupier, to repair a watercourse granted to him, &c. He is also justified in pulling down, for the safeguard of his own, his neighbour's house which is on fire. Where an act amounts to a felony it is not competent for the party injured to treat it as a trespass. (Comyn's 'Dig.,' 'Trespass.')

In the case of malicious injuries done to property by trespassers, a number of provisions have been enacted by 7 & 8 Geo. IV., c. 30. In many cases a jurisdiction is given to magistrates to inflict punishment on the offenders, to award compensation to the parties injured, &c.

TRET. [Tare.]

TRIADS. [Welsh Language and Literature.]

TRIAL, the means adopted for the purpose of ascertaining facts in issue, whether civil or criminal. The kinds of trial in civil cases were formerly seven in number, according to Blackstone; and those which he enumerates are, by record, by inspection or examination (divided into two distinct kinds by Comyns), by certificate, by witnesses, by wager of battle, by wager of law, and by jury. In reality the six first might more properly be called modes of proof rather than kinds of trial, which in truth divide themselves into two classes only: 1. That where the court itself decides upon the evidence without the intervention of a jury: 2. That where the jury decides.

The first class contains the first six enumerated by Blackstone; that *by record* is where the existence of a certain record has been alleged in the pleadings of an action and is denied by the pleadings on the other side. The existence of it must be proved by the record itself. The court itself tries this issue, and decides accordingly as such a record is, or is not produced. [Record; Records.]

Questions whether or not a party is a peer are thus proveable by the king's patent; whether an alien is friend or enemy, by production of the treaty between his country and Great Britain, &c.

By inspection was where it was supposed a matter might be clearly made manifest on view to the court. In error by an infant, to reverse a fine, if issue was taken as to his nonage, he might be brought into court and there inspected for the purpose of ascertaining the fact. If on his appearance it remained doubtful, the court might question him, or examine those likely to be informed. So where a defendant pleaded in abatement that the plaintiff was dead, and some one appeared and said that he was the plaintiff, &c. The court had at all times the power, if they felt doubt, to order a trial by jury. This mode of proceeding has now become obsolete.

By *examination* is upon inquiry by the court into, for instance, the customs and usages of a court.

By *certificates*. By certificate is where a fact is proved by the production of a certificate from a certain official person qualified to grant such certificate. Thus formerly the absence of a person from England during war might be tried by the court, and proved by a certificate of the "mareshal of the king's host." In the same manner the customs of the city of London are proved by the certificate of their recorder. A certificate of a bishop is proof respecting matters of ecclesiastical jurisdiction, &c.

By *witnesses*. In action of dower where the tenant pleads that the husband is alive, the court may inquire of the fact by witnesses called before themselves. Lord Coke mentions several other cases where the court itself decides upon the examination of witnesses; and he further states that in all such cases each fact must be proved by two witnesses at least. Although in the case of a trial by jury one witness, according to the English law, is sufficient.

By *wager of battle*. That is by single combat between the champions of the parties. [Appeal.] This proceeding was abolished by 59 Geo. III. c. 46.

The proof by *wager of law* was employed in an action of debt upon simple contract, of detinue, account, and some others. It was effected by the defendant coming into court attended by eleven of his neighbours who were called compurgators. He then solemnly swore that he did not owe the sum with which he was sought to be charged, or detain the thing sought to be recovered, and the eleven compurgators swore that they believed him. The wager of law had already fallen into disuse when it was wholly abolished by 3 & 4 Will. IV., c. 42.

The mode of trial always the one most in use both in civil and criminal matters, was the trial by jury. [Jury.]

In criminal cases recourse was anciently had to the ordeal for the purpose of ascertaining the guilt or innocence of a party [Ordeal], and also to the single combat. [Appeal.] It appears doubtful whether the ordeal fell into disuse, or was abolished by statute. Appeals in criminal cases were done away with by 59 Geo. III., c. 46.

A peer of Great Britain indicted capitally is entitled to be tried by the peers of parliament assembled in the court of the Lord High Steward of Great Britain, who is a peer nominated to that office by the crown for the occasion. The proceedings of the trial are carried on in the same way as on a trial by jury, and judgment is pronounced according to the opinion of the majority, which must consist of at least twelve. Cases of impeachment by the Commons are also tried by the Lords.

A trial at bar resembles the ordinary cases of trials by jury, except that instead of its being presided over by a single judge, all the judges of the court in which the action is brought are in attendance. It is granted on application to the court, but only in cases of great difficulty and importance. In informations exhibited by the attorney-general, as law-officer of the crown, he is entitled to a trial at bar.

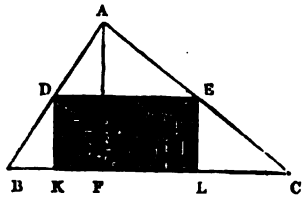
New Trial. After a trial has been already had, it is competent to the court in which the action is brought to grant a new trial on an application made, and grounds shown for supposing that justice has not been done between the parties; and that the case is of sufficient importance to warrant such a further expense. These grounds are various, such as a misdirection by the judge, a verdict against evidence, excessive damages, &c.

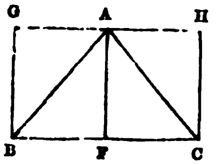
TRIAMYLAMINE. [ORGANIC BASES.]

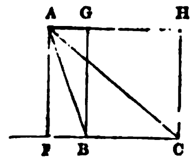
TRIANGLE, a figure having three angles, and consequently three sides: this consequence is usually made the definition; and the same thing occurs in Euclid, whose word is *τρίγωνον* in the Elements, though it is *τρίπλευρον* in the definitions prefixed.

A triangle may be drawn upon any surface, and having any sort of lines for its sides: but it is not usual to consider any except *plane* triangles drawn on a plane with right-lined sides, and *spherical* triangles drawn on a sphere with arcs of great circles for the sides. The SPHERICAL triangle has been already considered; and the formulæ connected with the plane triangle have been given in MENSURATION. There is much connected with this article in ANGLE, PARALLEL, SIMILAR, TRANSLATION, TRANSVERSAL, TRIGONOMETRY, &c., so that we have no need to make this article of a length proportioned to the importance of its subject in geometry. In fact, triangles are as much the elements of all figures as the letters are of words, being the figures of the smallest possible number of sides, and into which all figures can be divided.

The two most important properties of the triangle are, that the sum of its angles is always two right angles, and that the area is half that of a rectangle of the same base and altitude. Both of these propositions admit of such practical verification as would make them perfectly intelligible to those who do not understand geometry. Take the greatest angle BAC of a triangle cut out in paper, and fold the paper so that A may rest on BC at F, the part ADE folding over DFE. Then it will be found that by further folding ECL can be brought over EFL, and BDK over FDK, so that the three angles of the triangle KFD, DFE, and EFL are so placed that the first side of the first and the last side of the last, KF and FL, are in the same straight line, and the three make up the two right angles KFA, AFL. Again, the triangle BAC is either the sum or difference of the two right-angled triangles FAC, FAB, which are the halves of the rectangles FACH, FABG, the sum or difference of which is the rectangle BGHC: whence the triangle is the half of the rectangle BGHC, of the same base and altitude as the triangle.







The three lines which bisect the angles of a triangle meet in one point, which is the centre of the inscribed circle; and the three perpendiculars which bisect the three sides also meet in one point, which is the centre of the circumscribed circle. Moreover, the three lines drawn from the vertices bisecting the sides meet in one point, which is the centre of gravity of the triangle: as also do the three perpendiculars drawn from the vertices to the sides. All these propositions, except the second, can be proved by the same process, namely, by showing that the segments of the sides satisfy the theorem given in TRANSVERSAL.

The number of isolated theorems which might be given on this subject is very large, but there is little unconnected with the trigonometrical formulæ which is of use in application.

TRIANGULA and TRIANGULUM AUSTRALE (constellations). The first (the Triangles) is a northern constellation, surrounded by Perseus, Andromeda, Aries, and Musca. It is one of the old constellations, but there is only one triangle in Aratus. Hevelius added the second. The second, or Southern Triangle, is a constellation of Bayer, lying between Ara, Centaurus, and the South Pole.

The principal stars are as follow:—

TRIANGULA.

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
α	2	569	4
β	4	656	4

TRIANGULUM AUSTRALE.

Character.	No. in Catalogue of Lacaille.	No. in Catalogue of British Association.	Magnitude.
γ	1267	5005	2
β	1311	5233	3
α	1381	5578	2

TRIANGULAR COMPASSES. [COMPASSES.]

TRIANGULAR NUMBERS. [NUMBERS, APPELLATIONS OF.]

TRIANGULATION, a name given to the net-work of triangles with which the face of a country is covered in a TRIGONOMETRICAL SURVEY.

TRIARSENIO-METHYLAMINE. Synonymous with *trimethylarsine.* [ORGANOMETALLIC BODIES. *Arsenic Series.*]

TRIATOMIC ETHERS. [ETHERS.]

TRIBE (*tribus, φυλή*). All the states of antiquity of which we have any records were divided into a certain number of tribes, consisting of the great bodies of citizens of which the state was composed. These tribes, however, were of two different kinds, either genealogical (*γενικαί*) or local (*τοπικαί*). (Dionys. Hal., iv. 14.) The former, which must be considered as the more ancient of the two, were the different national elements of which a state was made up, that is, each was a distinct people, though akin to the others, and each traced its origin to some mythical ancestor; whence Dionysius calls such tribes genealogical. The other, or local tribes, to which a later origin must be assigned, and which in most cases superseded the old genealogical tribes, were artificial local divisions made for political and other purposes, and any one of them might contain people who, according to the genealogical division, would belong to different tribes. Thus we find in the history of Attica that the four original tribes were done away with after the institution of the ten local tribes by Cleisthenes; and at Rome the three ancient Romulian tribes which retained their political importance almost to the time of the decemviral laws, died away and ceased to be noticed in Roman history save as an archaic institution, the thirty local tribes established by the Servian constitution having gradually superseded them. At Sparta alone the three original Doric tribes, the Hylleans, Pamphylians, and Dymanians, were retained without any change. Genealogical tribes may, in many instances, as was originally the case at Rome, have inhabited different districts, so that they were at the same time local tribes; but this is merely an accidental circumstance.

The number of the genealogical tribes was different in the different states of antiquity, and depended upon various circumstances, such as the number of national elements brought together to form a state, or the partiality of a race of men for particular numbers which were used as typical. Thus we find that the Doric states were originally divided into three, the Ionic into four, and the Romans into three tribes, and, later on, into a multiple of these numbers. Although these tribes only contained freemen, they were not always on a footing of equality; but the most ancient one, to which the others had only been added at some time by treaty or contract, always retained, at least for a time, a superiority over the others, and reserved for itself rights and privileges which were denied to the others. Such was the case with the Hylleans at Sparta, the Eupatrids at Athens, and the Ramnes at Rome. Each tribe was usually subdivided into smaller bodies, as at Athens into *φρατρίαι* and *γένη*, at Sparta into *ὠβαί* and *τριακάδες*, and at Rome into curiæ and gentes. The number of senators and of the great officers of a state likewise bore a certain relation to the number of tribes or their subdivisions. The bond of union between such tribes was more or less loose according to circumstances; and the history of Attica gives us an instance of their being at war with one another. Each tribe had usually its separate religious observances and festivals, and the same was the case with its subdivisions.

All the tribes of which a state consisted formed the sovereign people (as at Rome the populus), which in many cases ruled over a subject population superior in numbers (*περίοικοι*, plebeians). When a Greek state sent out a colony to a foreign country, it appears to have been customary to divide the new state into the same number of tribes as that which existed in the mother-city, and the names also were retained; in some cases, as at Cydonia and Halicarnassus, both of which were Doric colonies, we only find mention of one tribe, which may have arisen from the fact that only members of one tribe of the mother-state took part in the establishment of the colony. (Wachsmuth, 'Hellenische Altherthumskunde,' ii. 1, p. 15, &c.)

In regard to the later or local tribes, it is clear from the name itself that each inhabited a distinct district, containing either one or more townships, which were called in Attica *δῆμοι*, and at Rome *vici* or *pagi*. Every citizen belonging to a tribe was obliged to have his name registered in a township of his tribe, though he was not bound to reside in the same in which he was registered and to which he belonged.

Each tribe, whether genealogical or local, managed its own affairs, and was headed by a tribune (*φύλαρχος*). The same was the case with the subdivisions of a tribe.

We have here only given a brief outline of the subject in general, as a more detailed account of the tribes in the different states of antiquity is given in the articles ATHENS; SPARTA; ROME, in GEOG. DIV.; CLEISTHENES; SERVIUS TULLIUS, in BIOG DIV.; DORIANS;

Ionians; and others. Compare, also, Wachsmuth, 'Hellen. Alterthum.,' ii. 1, p. 15, &c.; Hermann, 'Political Antiquit.;' Schömann, 'De Jure Publico Græcorum,' p. 165, &c.; Niebuhr, 'Hist. of Rome,' i., p. 306, &c.

TRIBROMANILINE. [Aniline.]

TRIBROMEUXANTHONE. [Euxanthic Acid.]

TRIBROMOBENZIN. Synonymous with *tribrombenzole.* [Benzole.]

TRIBROMO-PHENIC ACID. [Phenylic Group.]

TRIBROMO-SALICYLIC ACID. [Salicylic Group.]

TRIBUNUS (φύλαρχος), according to the etymology of the word, signifies any officer who is at the head of a tribe [Tribe], and conducts either the internal administration of a tribe, or represents it in its relations to other powers in the state. This signification applies indeed to some of the officers of this name who occur in the history of Rome, but in regard to others it must remain doubtful why they bore this name. The following is a list of all the Roman officers bearing the name of tribune.

1. *Tribunes of the Three Romulian Tribes.*—The existence of a tribune for the three ancient patrician tribes, the Ramnes, Tities, and Luceres, is attested by several passages of ancient writers. (Dionys. Hal., ii. 7; Servius, 'Ad Aen.,' v. 560; Pomponius, 'De Orig. Juris,' 'Digest,' i., 2, 2, 20.) As regards their functions we have no definite statements: they may have been intrusted with the management of the civil, religious, and military affairs of their respective tribes.

2. *Tribunus Celerum* is an officer who only occurs in the history of Rome during the period when it was governed by kings. He was the commander of the 300 equites (celeres) who formed the king's bodyguard, 100 being taken from each of the three tribes. He was, next to the king, the first person in the state. (Dionys. Hal., ii., 64; Pomponius, 'De Orig. Juris;' 'Digest.,' 1, 2, 2, 15.) In the absence of the king, the tribunus celerum acted as his representative, and convoked the senate, as well as the comitia of the curiæ, at which he presided.

3. *Tribunes of the Servian Tribes.*—When Servius Tullius organised the body of plebeians by dividing them into thirty local tribes, each of them was headed by a tribune, who had to keep a register of the inhabitants of his district and of the condition of every household in it. (Dionys. Hal., iv. 14; and Varro, 'De Vit. Pop. Rom.,' i. 240.) The scrutiny into every household appears to have gradually ceased, partly because it was repugnant to the spirit of liberty, which was rapidly developing, and partly because the state obtained sufficient information through the census. When subsequently the Roman people became exempt from taxes, the main functions of the tribunes ceased, but they themselves continued to exist, nor is it improbable that the tribuni ærarii, who are mentioned from the time that pay began to be given to the soldiers (B.C. 406) down to the end of the republic, are the same as the tribunes of the Servian tribes. (Niebuhr, 'Hist. of Rome,' i. p. 421.) The tribuni ærarii had to levy the tribute in their tribes and to pay the soldiers with it. (Varro, 'De Ling. Lat.,' v. § 181; Gellius, vii. 10.) After the institution of the quæstors, the tribuni ærarii had only to levy the tribute and hand it over to the quæstors, who distributed the pay among the soldiers. The Lex Aurelia, B.C. 70, gave to these tribunes judicial power along with the senators and equites; but they were deprived of it by J. Cæsar. (Sueton., 'Cæs.,' 41.)

4. *Tribuni Plebis.*—These were the most important among the many officers bearing the name of tribune; and whenever tribunes are mentioned without any further qualification, the tribuni plebis are meant. In the year B.C. 494, when the plebeians had been driven by the oppression of the patricians to secede to the Mons Sacer, peace was concluded between the two orders on condition that the plebeians should be allowed to have magistrates of their own, whose province it should be to protect the members of their order against the patrician magistrates, and whose persons should be sacred and inviolable. It was farther agreed, that whoever should maltreat, kill, or compel a tribune to anything by force, should be outlawed and his property should be forfeited to the temple of Ceres. (Liv., ii. 33 and iii. 55; Dionys. Hal. vi., pp. 89, and vii. 17.) These agreements, however, were insufficient to protect the tribunes against various annoyances of the patricians; hence it was found necessary, soon after the institution of the tribunate, to give still more security to the exercise of their power. A law was accordingly passed forbidding any one to interrupt or disturb the tribunes in their transactions with the plebs, and enacting that any one who should act contrary to this law should give bail to the tribunes for any fine inflicted upon him; those who refused to give bail forfeited their life and property. The inviolability of the tribunes was finally established after the time of the decemvirate by a law of M. Horatius.

With regard to the conflicting statements as to the number of the tribunes, the probability is in favour of the number five, so that one was taken from each of the five Servian classes. Thus much only is certain, that in the year B.C. 457 the number of tribunes was increased to ten; so that if they really bore any relation to the classes, each furnished two. This number remained unaltered to the end of the republic. The tribunes were attended by public servants, called viatores, who carried their commands into effect.

The accounts about the manner in which the tribunes were originally elected are as contradictory as the statements about their original number. The statement of Dionysius and Cicero, that they were elected by the curiæ, must either have arisen from a misunderstanding of the nature of the curiæ, or from a confusion of the election and the sanction of the election; for the latter was a right which the curiæ unquestionably possessed for a time. If, as Niebuhr thinks, they were intended to represent the classes, they were elected by the centuries; but it is much more probable that the college of tribunes, at the expiration of the year of office, appointed their successors, after a previous consultation with the plebs. The sanction of the curiæ ceased to be necessary shortly before the time of the Publilian law; and after that time we have express testimonies that the tribunes were elected by the comitia of the tribes, under the presidency of one of the tribunes whose office was expiring. (Livy, ii. 56, &c.; iii. 64; Dionys. Hal., ix. 2.) As it was necessary that all the tribunes should be elected on one day and before sunset, it often happened that when the business of election could not be completed within the lawful time, those who were elected had to fill up the number by co-optatio. This inconvenience was done away with in 448 by the tribune L. Trebonius, who got a law passed, ordaining that in future the elections should be continued the next day or days in cases where one day should be too short a time to complete them.

The field of action for the tribunes were the comitia of the tribes and other meetings of the plebeians; and they arraigned before the assembly of the plebs any one, whether private individuals or magistrates, who had violated the rights of the commonalty, and that without any fear of being interrupted in their proceedings. They themselves had no judicial power; they had only the right to drag the offender before the assembly of the people, and to propose a fine to be inflicted on him. In later times they sometimes deviated from this rule, and assumed the right of proposing capital punishment. Their lawful power was originally mere *auxilium;* that is, to afford protection, without any right directly to interfere in the affairs of the state. Their power, the Tribunicia Potestas, or Tribunicium Jus, was confined to the city and one mile beyond its walls. They were not allowed to spend a night outside the city, except during the Feriæ Latinæ, when all the people were assembled on the Alban Mount. The house of a tribune was regarded as a place of refuge for any one who thought himself wronged or oppressed, and the doors were left open by night as well as by day. From the first the plebeians regarded the tribunes not only as their protectors against patrician oppression, but as arbitrators in matters among themselves. (Walter, 'Geschichte des Röm. Rechts,' p. 85.) The power of the tribunes, after it was once established, rapidly increased in proportion as the commonalty itself increased in importance; indeed we may say that the growing importance of the commonalty was the work of the tribunes. Not quite forty years after the institution of the tribunate we find the members present at the deliberations of the senate; and in B.C. 454 the tribunes compelled the senate to meet, in opposition to the consuls, that they might lay before them a rogation and discuss its merits. Henceforth either the tribunes themselves, or the consuls at their request, proposed legislative measures to the senate, as we see in the instance when a new legislation was demanded by the tribunes. This demand of the tribunes, after some struggles on the part of the patricians, was at last complied with, and led to the appointment of the decemvirs, for the purpose of framing a new code of laws. During the second decemvirate the tribunate was suspended, like all other magistrates; but when the business of legislation was completed tribunes were again appointed, and it was on their proposition that the consulship also was restored. (Liv., iii. 54.)

The position of the tribunes after the decemviral legislation was very different from what it had been before. Henceforth we find the patricians and the clients contained in the tribes, and the tribunes now stand in the same relation to the whole nation as they had before stood to the commonalty only: they are now the protectors of the whole nation as assembled in the comitia of the tribes, and in opposition to the senate and the magistrates; they are the representatives of the democratical element in the state, in opposition to the aristocratical. This explains how it happened that their protection was sought by patricians as well as plebeians. (Liv., iii. 56; viii. 33, &c.) They henceforth also appear in the possession of the right of being present at all the deliberations of the senate; but their place was outside the opened doors, where they sat upon benches. They had at all times the right to propose measures to the assembly of the tribes, which might pass them. Such resolutions of the tribes were called plebiscita, and required the sanction of the senate or the curiæ before they became laws. But the Lex Valeria ordained that all plebiscita should be binding upon the whole nation without any further sanction. ('Dictionary of Greek and Rom. Ant.,' under "Plebiscitum.") This gave to the tribunes an extraordinary influence in all the affairs of the state, and the democratical element had now gained the superiority. But while the power of the tribunate was thus outwardly increasing, a change took place within the body, or collegium, as it was called, which, to some extent, paralysed its power. Down to the year B.C. 394 all matters had been decided in the college of the tribunes by a majority of the members, but in this year we meet with the first instance of the intercession (veto) of one tribune rendering the resolution of his colleagues void. (Liv., v. 25, 29.) It is uncertain what gave rise to this innovation; but it weakened the power of the college, inasmuch as the aristocratic party might easily gain over one of its members, and thus thwart the plans of the rest. In such a case nothing could be done, and the matter was dropped. C. Tiberius Gracchus was the first who pointed out the manner in which the college might get rid of an obstinate member: he proposed to the people to deprive such a tribune of his office—an expedient which was afterwards occasionally made use of. The same power, however, which a tribune had over the resolutions of his colleagues he also had upon the proceedings of a magistrate, whether a consul, a censor, or a prætor, and even over an ordinance of the senate. The right of the tribunes of merely appearing in the senate was gradually increased by the power of convoking the senate, and laying before it any measure relating to government or administration; and the senate had often recourse to the tribunes for the purpose of compelling magistrates to comply with its wishes. (Liv., iv. 26; v. 9; xxviii. 45.) At last it was established by the Plebiscitum Atinium that a tribune should be a member of the senate by virtue of his office. The time when this plebiscitum was passed is uncertain, though it is not improbable that it originated with C. Atinius, who was tribune in B.C. 130.

There was no power in the Roman republic that could be compared to that of the tribunes, and during the latter period of the republic they formed a real democratical senate. But whatever may have been the abuse that some tribunes made of their exorbitant power, and however much evil they may have produced, yet it is a point acknowledged on all hands that Rome owed her greatness, in no small degree, to the institution of the tribunate.

Sulla, in his attempt to remodel the constitution upon aristocratic principles, reduced the powers of the tribunes to what they had been originally. But this innovation, like all his constitutional changes, was a complete failure, and the full power of the tribunes was restored to them by Pompey. [Sulla, and Pompey, in Biog. Div.]

During the empire the college of tribunes of the people continued to exist; and in the reign of Augustus comitia for the election of tribunes were still held, although the freedom of election gradually disappeared. (Sueton., 'Aug.,' 40; Vellei. Pat., ii. 111.) The political influence of the tribunes also sank rapidly, and even at an early period of the empire we find it almost confined to intercession in decrees of the senate and to protecting oppressed or injured individuals. (Tacit., 'Annal.,' xvi. 26; 'Histor.,' ii. 91; iv. 9; Plin., 'Epist.,' i. 23; ix. 13.) Tribunes, however, continued to exist down to the 5th century of our era; and though their power was much limited, they still continued to be looked upon as the protectors of the weak and the injured, which made their office one of great moral importance. For this reason, as well as for the purpose of having a check upon the college, the emperors, although patricians, found it necessary to be tribunes. In fact, the office of tribune, all the other magistracies being united in one person, was the only thing that was wanting to complete the sovereign power of an emperor. This tribunicia potestas of an emperor was conferred upon him by the senate, and was justly deemed equivalent to regal or dictatorial power with a popular name, so that the tribunicia potestas became an essential part of the imperial dignity, and was finally established as such by the Lex de Imperio Vespasiani. (Suet., 'Tiber.,' 23; 'Vespas.,' 12; 'Titus,' 6.)

5. *Tribuni Militum cum Consulari Potestate.*—In the year B.C. 445 the tribune C. Canuleius carried several rogations, one of which was, that the people should be at liberty to elect the consuls from the patricians and plebeians indiscriminately. In order to avoid the consequences of this law, the senate decreed that instead of consuls, tribuni militum with consular power should be elected promiscuously from both orders; and in order that the plebeians might not gain too much at once, the censorial power, which had hitherto been a part of the consular power, was separated from it and given to two new patrician officers, the censors. Accordingly in the year 444 B.C. three tribunes were elected instead of consuls, one of them being a plebeian. The people however were allowed for the following years to elect either tribunes or consuls, as they might think proper. The consequence was, that for a series of years sometimes consuls were elected according to the old custom, and sometimes tribunes. From the year B.C. 426 the number of tribunes varied between three and four, until in B.C. 405 it was increased to six, which remained unaltered down to the year B.C. 366, when the office of the military tribunes with consular power was abolished, and the consulship restored. These consular tribunes, as they are briefly called, had the same power as the consuls, with the exception of that part of it which had been detached from it and given to the censors. For this and other reasons the patricians did not so much object to its being shared with the plebeians, as they did in regard to the consulship, which was sanctified by solemn auspices.

6. *Tribuni Militares*, or *Militum*, or tribunes of the soldiers, were a class of officers in the Roman armies, of whom at first there were four in a legion. They appear originally to have been appointed by the consuls, but in the year B.C. 363 it was decreed that henceforth half of them should be elected by the people in the comitia of the centuries, while the appointment of the other half was left to the commanders of the legions as before (Liv. vii. 5); and as there were six in a consular army, three were elected by the people and three by the consul. The latter were, down to the latest time of the republic, called *ruffuli*, and the former *comitiati*. (Festus, s. v. 'Ruffuli.') In later times the number of tribunes for each legion was increased to six, and their appointment was sometimes left altogether to the consuls. But this seems to have been an exception to the rule, for subsequent to that time we again find that the people had the election of a part of the tribunes. (Liv., xliii. 14 and 31; xliv. 21.) The functions of these tribunes of the soldiers consisted in maintaining the discipline among the troops, superintending their exercises and their state of health, in inspecting the sentinels, settling disputes among the soldiers, in taking care that they received their necessary provisions, and the like.

TRICHI'ASIS (τριχίασις), is a disease in which one or more of the eyelashes are turned inwards, so as to be in contact with the front of the eyeball. The irritation thus excited produces all the pain and other symptoms of inflammation of the conjunctiva, and if long continued may terminate in opacity of the cornea and complete blindness.

The wrong direction of the eyelashes may depend on various causes. Sometimes it appears to be their natural mode of growth; one or more growing differently from the rest, and being reproduced with the same faults as often as they are extirpated. More frequently it is due to some disease of the eyelid, producing a cicatrix or induration of its inner surface, which, contracting, draws in the margin of the lid, and with it the lashes. By a similar process, trichiasis is the constant accompaniment of the cases of entropium, or inversion of the eyelids, which depend on induration or contraction of their cartilages.

A temporary remedy for trichiasis is the extraction of the offending eyelashes, which may be effected by plucking them with broad-pointed forceps; but they are generally quickly reproduced, and, growing in the same direction, renew the patient's suffering. For a permanent remedy, some of the operations for entropium must be performed, or the portion of the inner margin of the eyelid from which the inverted lashes grow must be removed with their bulbs.

TRICHLORACETIC ACID. [Chloracetic Acid.]

TRICHLORALDEHYDE. [Chloral.]

TRICHLOR-EUXANTHONE. [Euxanthic Acid.]

TRICHLOROKINONE. [Kinic Acid.]

TRICHLOROMETHYL-DITHIONIC ACID ($C_2Cl_3HS_2O_6+2aq.$). *Trichloromethyl-Sulphurous Acid.* An unimportant organic acid obtained by treating trichloromethyl-sulphurous chloride with potash or baryta. This acid has also been named *chlorocarbo-hyposulphuric acid.*

TRICHLOROMETHYL-SULPHUROUS ACID. [Trichloromethyl-Dithionic Acid.]

TRICHLORONAPHTHALIC ACID. [Naphthalic Group, *Trichlorophthalic Acid.*

TRICHLOROPHENIC ACID. [Phenylic Group.]

TRICHLOROVALERISIC ACID. [Valerianic Acid.]

TRIDENT (*tridens*, τρίαινα) is any instrument of the form of a fork, with three prongs; instruments of this kind were used by the ancients, as among ourselves, for various purposes. In mythology the trident is the attribute of several marine divinities, such as Nereus (Virg., 'Æn.,' ii. 418) and the Tritons (Cicero, 'De Nat. Deor.,' ii. 35), but above all of Poseidon. The trident in these cases is the same as the sceptre with other gods, the emblem of the power of these gods of the waters. The ancients regarded earthquakes as arising from the sea, or, as they expressed it, as the work of Poseidon, who effected them by his mighty trident, whence Homer frequently calls him the "shaker of the earth," and whenever the god is represented as producing any convulsion of the earth or the sea, the trident is always mentioned. (Hom., 'Odyss.,' iv. 506; Claudian, 'De Rapt. Pros.,' ii. 179.)

TRIETHYLAMINE. [Organic Bases.]

TRIETHYLPHOSPHINE. [Organic Bases.]

TRIFO'RIUM, an upper gallery formed by small open arches above those dividing the nave from the side-aisles of a church, and beneath the clerestory windows, this intermediate tier being within the sloping roof over the aisles. These galleries are, in this country, sometimes called "Nunneries," but in Germany "Männerchor." They are not confined to the nave, but continued in the transepts, so as to afford a passage almost entirely round the upper part of the building. In general the triforium is very shallow or narrow, and the arches in front of it are small and low; and of these last, there are two, three, or even six, over each of the larger arches separating the nave from the aisles. There are however very great differences in these respects even in buildings of the same period and style. In some instances the triforium is very lofty and open, as in the Abbaye aux Hommes, Caen, and in the choir of Bayeux Cathedral, although the nave of the same edifice offers an example directly the reverse, the triforium consisting there of a range of very low and small arches; while the clerestory windows are remarkably large and lofty, much larger in fact than the pier-arches between the nave and aisles. In the Norman naves of some of our cathedrals the triforium arches are as wide and nearly as high as those of the aisles; and the triforium itself is so spacious as to form an upper aisle, lighted, like the lower one, with windows. Norwich is an example of this kind, as is likewise Peterborough, except that in the latter the large triforium arches corresponding with those below are subdivided into two lesser ones with a column between them. At Gloucester, on the contrary (also Norman), the triforium arches are low and small, being divided at first into two, each of which is again similarly subdivided, so as to make four openings over each of the large arches below. In the nave of Wells Cathedral the triforium consists of an uninterrupted range of small arches of peculiar character, in which the openings are very narrow in proportion to the solid parts or moulded piers between them. In English churches triforia are, during the First Pointed period, very ornamental in character; in the Second and Third Pointed styles they are generally smaller and less important.

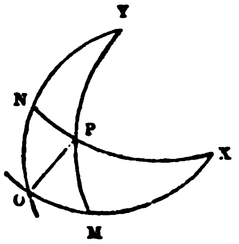
TRIGENIC ACID ($C_8H_7N_3O_4$). Aldehyde absorbs the vapour of cyanic acid with great avidity, producing a white crystalline mass, whilst carbonic acid is disengaged. Amongst other substances, trigenic acid is formed by the following reaction:—

$$\underbrace{C_4H_4O_2}_{\text{Aldehyde.}} + \underbrace{3CyHO_2}_{\text{Cyanic acid.}} = \underbrace{C_8H_7N_3O_4}_{\text{Trigenic acid.}} + 2CO_2$$

Trigenic acid crystallises in small prisms, very slightly soluble in water or alcohol. When submitted to destructive distillation, it appears to yield quinoleine and cyanuric acid. The trigenate of silver is insoluble in cold water, but soluble in hot water.

TRIGLYPH. [GRECIAN ARCHITECTURE.]

TRIGONOMETRICAL CO-ORDINATES. These co-ordinates were invented, independently of each other, by Professor Gudermann, of Cleves, and the Rev. Charles Graves, of Trinity College, Dublin. The latter called them *spherical co-ordinates*, a term which is liable to be confounded with the common astronomical co-ordinates described in SPHERE. This remarkable extension leads to a system of algebraic geometry for curves on a sphere, singularly resembling in its results the common system in a plane, many of the formulæ of the two being absolutely identical. We venture to predict that many difficulties of common algebra, arising from the entrance of the consideration of infinity, will find easy and natural explanations when the common system is considered to be, as it really is, an extreme particular case of this more general view.



Through any point O on a sphere, let arcs OX and OY be drawn, which represent the axes of x and y. Let OX and OY be each of them quadrants, and through any point P let arcs YM, XN be drawn. Then the trigonometrical co-ordinates of the point P are the tangents of OM and ON, or of the angles subtended by them at the centre. These tangents are called x and y. If the whole system be projected, by lines drawn from the centre of the sphere, upon the tangent plane at O, then OM and ON will be projected into rectilinear co-ordinates to the projection of P. The equation of a great circle is of the first degree, or of the form $ax+by+c=0$, and an equation of the nth degree belongs to the intersection of the sphere with a cone of the nth degree whose vertex is at the centre. In the polar co-ordinates OP is the radius of the point, and the angle POM its angle. This system of polar co-ordinates had been previously considered by Mr. T. S. Davies ('Trans. R. S. Edinb.,' vol. xii.), at great length, and with valuable results. Mr. Graves published his account of the trigonometrical co-ordinates in the appendix to his 'Two Geometrical Memoirs on the General Properties of Cones of the Second Degree,' &c.; Dublin, 1841.

The complete algebra [NEGATIVE, &c., QUANTITIES] may be easily applied to this system. If, in fact, the *tangent* of OP were called the radius vector, instead of OP, and denoted by r, the angle POM being θ, we should have, for rectangular co-ordinates, exactly as in the plane system,

$$x=r\cos\theta,\ y=r\sin\theta,\quad x+y\sqrt{-1}=r\varepsilon^{\theta\sqrt{-1}}$$

TRIGONOMETRICAL CURVES, a name given to curves having such equation as $y=\sin x$, $y=\cos x$, $y=a\cos x+b\cos 2x$, &c. To construct the forms of such curves from the knowledge of the fundamental properties of the sine, cosine, &c., should be an early exercise of the student in trigonometry, and will be of use in his subsequent reading.

TRIGONOMETRICAL SERIES. Infinite series which are of the form $a\sin x+b\sin 2x+c\sin 3x+$ &c., and $a\cos x+b\cos 2x+c\cos 3x+$ &c., are of important use in the higher parts of mathematics. The common mode of finding their equivalents, when $a+bz+cz^2+$ &c., admits of representation in a finite form, is very easy. For instance, let it be required to find $1+a\cos x+a^2\cos 2x+$, &c. Assume $2\cos x=z+z^{-1}$, then $2\cos nx=z^n+z^{-n}$, and substitution gives for the whole series,

$$\frac{1}{2(1-az)}+\frac{1}{2(1-az^{-1})}\ \text{or}\ \frac{2-a(z+z^{-1})}{2(1-a(z+z^{-1})+a^2)}$$

$$\text{which is}\ \frac{1-a\cos x}{1-2a\cos x+a^2}$$

The most remarkable property of these series is that they are capable of representing discontinuous lines, so that an arc composed of arcs of different curves might have every one of its points made to satisfy an equation of either of the preceding forms. The whole of the discontinuous undulation, for instance, drawn in ACOUSTICS might be included under one equation. See the 'Differential Calculus' ('Library of Universal Knowledge'), p. 621. In the higher parts of physics, this property is of the greatest importance; and without doubt it is one of the most remarkable in the whole range of analysis. But it will not perhaps appear so singular if we remember that every curve made of arcs of different curves can have a continuous curve, represented even by a common algebraical equation, drawn as near as we please to any collection of its arcs. Lagrange showed the use of a finite trigonometrical series to be a very easy mode of actually representing the ordinate of this approximate curve: the infinite trigonometrical series is the limit which actually attains, algebraically speaking, the perfect representation of that to which a finite number of terms is only an approximation.

TRIGONOMETRICAL SURVEY. [GEODESY.]

TRIGONOMETRICAL TABLES. The chronological list given in TABLES will serve as a sketch of the history of these tables: we desire here to elucidate a point of their construction which, in the present state of transition from one system of definitions to another [TRIGONOMETRY], causes a great deal of confusion.

In the ordinary trigonometrical tables is set down the common or Brigg's logarithm of the sine, cosine, &c., of every angle which is an exact number of minutes (or seconds, or ten seconds, as the case may be) from 0° to 90°. Looking into a table we find for the logarithm of the sine of 35°, for instance, 9·7585913. This number is the logarithm of 5735764363, a number containing nearly six thousand millions of units. But the constructors of these tables used a radius of ten thousand millions of units, and their assertion consequently is, that if a right-angled triangle have ten thousand millions of units in its hypothenuse, and 35 degrees in one of its angles, the side opposite that angle will be 5735764363, which is correct within one unit. The logarithm of this radius is ten, and the earliest tables were constructed so as to give ten figures of the logarithms, from which ten significant figures of the sine, &c., might always be found: this radius was therefore convenient. Those who use the old system strictly, and employ the radius in every formula, find no difficulty: thus, if c be the hypothenuse of a spherical triangle, and a and b its sides, we have

$$\cos c=\frac{\cos a\,.\cos b}{r}$$

$$\log\cos c=\log\cos a+\log\cos b-\log r\ (\text{or }10).$$

But those who use the old system, and have also dropped into the habit of making the radius always unity, or omitting it from the formulæ, and those who use the new system, in which the sines, &c., are numerical representations of ratios, will always find a difficulty, until they establish a new explanation of the characteristic of logarithms which they find in their tables. We speak of course of beginners, for practice will get over such a discrepancy, or will perhaps cause a sufficient explanation to suggest itself.

To either of the two last-mentioned classes of persons, the sine of 35° is ·5735764363, and its real logarithm is the negative quantity ·7585913−1, or −·2414087. To them therefore the simple explanation of the discrepancy between their logarithm and that of the tables is as follows:—The *tabular* logarithm is always 10 more than the *real* logarithm, and the real logarithm always 10 less than the tabular logarithm. There are two ways of proceeding: either to take out the real logarithm, which can always be done, using the characteristic −1 (or for distinction, $\overline{1}$) instead of 9, −8 or $\overline{8}$ instead of 2, −3 or $\overline{3}$ instead of 7, and so on; or to remember that each logarithm is 10 too great, and to make the correction, either mentally or at the end of each logarithm. We have always found the first mode the better of the two, and we should recommend no one to reject it without a sufficient trial.

For example, suppose it is required to calculate $\tan\theta=\sqrt{(\sin 1^\circ\sin 14^\circ\div\sin 3^\circ)^3}$. We have (not using the arithmetical complement)

$$\begin{array}{rr}
\log\sin 1^\circ & \overline{2}\cdot2418553\\
\log\sin 14^\circ & \overline{1}\cdot3836752\\ \hline
\text{add} & \overline{3}\cdot6255305\\
\log\sin 3^\circ & \overline{2}\cdot7188002\\ \hline
\text{subtract} & \overline{2}\cdot9067303\\ \hline
 & 3\\ \hline
\theta=1^\circ\,19' \quad & 2)\overline{4}\cdot7201909\\ \hline
 & \overline{2}\cdot3600955
\end{array}$$

In looking for the result, we remember that the tabular logarithm answering to $\overline{2}$·3600955 is 8·3600955.

For the multiplication and division of negative characteristics, see LOGARITHMS, USE OF (col. 336).

TRIGONOMETRY. This word signifies the measurement of triangles, but we might as well attempt to confine geometry within etymological limits, as the science of which we are going to give some account in this article: the measurement of the earth is now only an isolated application of the former; and the measurement of triangles, of the latter.

In the modern division of the mathematical sciences, trigonometry, though still defined in books as the art of measuring triangles, really means the consideration of alternating or periodic magnitude; in which quantity is imagined to go through alterations of increase and diminution without end; that is ϕx, a function of x, is trigonometrical, when, as x varies through all stages of magnitude (or, in technical language, increases from $-\infty$ to $+\infty$), it takes an infinite number of alternate increases and diminutions. It is perfectly possible to contrive a common algebraic function which shall go through any given number of such changes—a thousand, a million, or more; but without recourse to infinite series, it is impossible to find one in which the number of alternations is unlimited. If the properties of algebraical series were as visible to the unassisted apprehension as those of figure in geometry, it would be seen that the two following series (afterwards known as those for the sine and cosine of x),

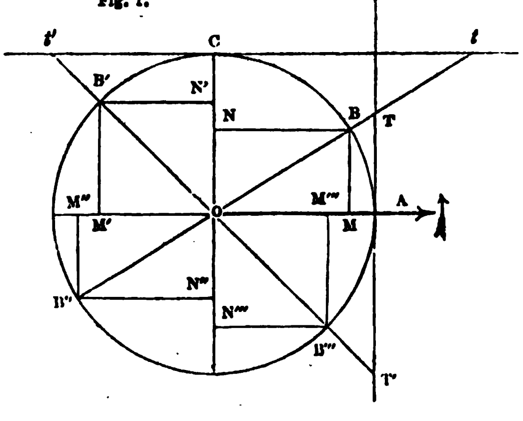
$$x - \frac{x^3}{2.3} + \frac{x^5}{2.3.4.5} - \text{\&c., and } 1 - \frac{x^2}{2} + \frac{x^4}{2.3.4} - \text{\&c.},$$

are periodic in value: and that, π being a certain incommensurable number (3·141592....), all the changes of magnitude that they can possibly take are only repetitions of what take place while x increases from 0 to 2π. We cannot form a more adequate idea of an intelligence superior to that of the human race, than by imagining one to which this truth should be, in consequence of sufficient rapidity of power of computation, a purely elementary one. We are obliged to come by this knowledge through our perceptions of space, and by the application of algebra to geometry; and the construction and use of our alphabet for the expression of periodic magnitude is contained in what are called the elements of trigonometry.

The most simple notion of periodic magnitude lies in supposing that the changes made are purely cyclical, or repetitions of the same for ever; as for instance, those which occur in turning a handle in a vertical plane. The number of revolutions traced out by the handle may be as great as we please, and the quantity of length of the circular arc described by its extremity may be as many times the circumference of the circle as we please, that is, as long as we please; but the distance of the handle from the ground is periodic, exhibiting perpetual increase and diminution as it rises and falls. Hence the circle naturally becomes a sort of standard of reference, and circular motion the primary idea, in all consideration of periodically changing magnitude. The arc, or the angle which it subtends at the centre, is the magnitude which increases without limit, all past revolutions being counted; and the lines which only depend on the position of the moving point in the circle, and not on the number of revolutions by which it has attained that position, are the periodic magnitudes in terms of which all others are expressed.

The periodic magnitudes connected with a varying angle, so far as they have separate designation, are the sine, cosine, tangent, cotangent, secant, cosecant, versed sine, coversed sine, and chord. A change has taken place in the mode of conceiving these quantities, and one which it is very desirable thoroughly to establish: though slight in appearance, and producing no difference in results, it gives a great advantage in the consideration of formulæ. These elements *were* lines; they now often *are*, and in future always *will be*, the ratios of lines to lines. The following figure exhibits the old definitions:—

Fig. 1.



Let O be the centre of a circle, and A O B an angle measured from a fixed radius O A, the direction of revolution in which angles are measured positively being denoted by the arrow. From B draw B M perpendicular to O A, and at A and C draw tangents to the circle. Then, in these old definitions, B M is the sine, O M the cosine, A T the tangent, C t the cotangent, O T the secant, O t the cosecant, A M the versed sine, C N the coversed sine, of the angle A O B. If A B should make a complete revolution, so as to come into the same position again, the angle under consideration would now be

four right angles + ∠ A O B,

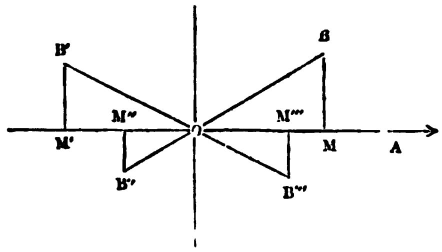
but the sine, cosine, &c. would all be the same as before.

As the line O B moves round, the signs of all these lines are to be taken positively when they are in the same directions as when A O B is less than a right angle. The following table will show them for the angles A O B, A O B', A O B'', A O B''', all measured in the same direction of revolution:—

Angle.	Sine.	Cosine.	Tangent.	Cotangent.	Secant.	Cosecant.	Versed Sine.	Coversed Sine.
A O B, less than a right angle.	BM	OM	AT	Ct	OT	Ot	AM	CN
A O B', between one and two right angles .	B'M'	−OM'	−AT'	−Ct'	−OT'	Ot'	AM'	CN'
A O B'', between two and three right angles .	−B''M''	−OM''	AT	Ct	−OT	−Ot	AM''	CN''
A O B''', between three and four right angles .	−B'''M'''	OM'''	−AT'	−Ct'	OT'	−Ot'	AM'''	CN'''

In this system an angle has an infinite number of lines of each sort, one to every radius which can be taken. It is therefore necessary, either to introduce into the formulæ the value of the radius in every case, or to adhere to some one particular value of the radius, which is always understood. The plan usually adopted is first to embarrass the formulæ with the general value of the radius, then gradually to accustom the student to consider the radius as one unit, but to make an exception when trigonometrical tables are used, by considering the radius as ten thousand millions. These inconveniences are avoided in the new system of definitions, which is as follows:—

Fig. 2.



From any point in the line O B (or O B', &c.) which is the variable boundary of the angle, draw B M (or B'M', &c.) perpendicular to O A. Let O M and M B be positive, O M' and M''B'', &c., negative, as in the usual method of reckoning co-ordinates. Call B M, B'M', &c., opposite to the angles, O M, O M', &c., adjacent; and let O B, O B', &c., be called hypothenuses (and always considered positive). Then the sine of B O M is the fraction which B M is of O B, with its proper sign, in this case positive: but the sine of A O B'' is the fraction which M''B'' is of O B'', taken negatively, because M''B'' is negative. It is indifferent what hypothenuse is taken, by the property of similar triangles, and the following is the complete system of definitions, with the values written for the four angles. They give a slight degree more trouble at first, which is amply compensated in the superior ease with which all formulæ may be deduced, to say nothing of the advantage of avoiding the indefinite radius.

Definition.	AOB	AOB'	AOB''	AOB'''
Sine = $\frac{\text{Opp}^{\text{e}}\text{. side}}{\text{hypothen.}}$	$\frac{BM}{BO}$	$\frac{B'M'}{B'O}$	$-\frac{B''M''}{B''O}$	$-\frac{B'''M'''}{B'''O}$
Cosine = $\frac{\text{Adj}^{\text{t}}\text{. side}}{\text{hypothen.}}$	$\frac{OM}{OB}$	$-\frac{OM'}{OB'}$	$-\frac{OM''}{OB''}$	$\frac{OM'''}{OB'''}$
Tangent = $\frac{\text{Opp}^{\text{e}}\text{. side}}{\text{Adj}^{\text{t}}\text{. side}}$	$\frac{MB}{MO}$	$-\frac{M'B'}{M'O}$	$\frac{M''B''}{M''O}$	$-\frac{M'''B'''}{M'''O}$
Cotangent = $\frac{\text{Adj}^{\text{t}}\text{. side}}{\text{Opp}^{\text{e}}\text{. side}}$	$\frac{MO}{MB}$	$-\frac{M'O}{M'B'}$	$\frac{M''O}{M''B''}$	$-\frac{M'''O}{M'''B'''}$
Secant = $\frac{\text{Hypothen.}}{\text{Adj}^{\text{t}}\text{. side}}$	$\frac{QB}{OM}$	$-\frac{OB'}{OM'}$	$-\frac{OB''}{OM''}$	$\frac{OB'''}{OM'''}$
Cosecant = $\frac{\text{Hypothen.}}{\text{Opp}^{\text{e}}\text{. side}}$	$\frac{BO}{BM}$	$\frac{B'O}{B'M'}$	$-\frac{B''O}{B''M''}$	$-\frac{B'''O}{B'''M'''}$

Versed sine = unity − cosine
Coversed sine = unity − sine.

The chord has long ceased to be regarded as one of the trigonometrical functions, and is always used in its old sense, as the line joining the extremities of an arc.

We shall now make a collection of the principal trigonometrical formulæ, and properties of the fundamental functions, referring to ANGLE for the modes of measuring angles, to SINE for development of several of the most important points, to SERIES for the expansions of various functions, to MENSURATION and SPHERICAL for the formulæ particularly connected with triangles, and to ALGEBRA, ROOT, SUBSIDIARY ANGLE, &c., for various other usual applications.

1. No sine nor cosine exceeds unity; no secant nor cosecant is less than unity; a tangent or cotangent may have any value; versed sines and coversed sines are always contained between 0 and 2, both inclusive.

2. With the sines and cosecants must be remembered the succession + + − −; with cosines and secants, + − − +; with tangents and cotangents, + − + −. Thus when an angle is in the *third* right angle, or lies between two and three right angles, its cosine is negative, — being the third sign of the succession + − − +. Versed sines and coversed sines are always positive.

3. With the different functions must be remembered the following series of initial values, being those at the beginning of the several right angles: thus—

$$\sin 0=0,\ \sin(r^t\angle)=1,\ \sin(2r^t\angle^s)=0,\ \sin(3r^t\angle^s)=-1$$

sine	0	1	0	−1	cosine	1	0	−1	0	tangent	0	∞	0	∞
cosecant	∞	1	∞	−1	secant	1	∞	−1	∞	cotangent	∞	0	∞	0

4. To find a function of any number of right angles increased or diminished by a given angle, take the same function, if the number of right angles be even, its *cofunction* (sine for cosine, cosine for sine, &c.) if the number of right angles be odd: put that sign which belongs to the given function in the right angle to which the whole given angle belongs when the increment or decrement is less than a right angle. Thus we have

$$\sin\left(3\,\frac{\pi}{2}-\theta\right)=-\cos\theta,$$

which is thus obtained: the odd number of right angles ($\frac{1}{2}\pi$ representing a right angle) is a direction to put *cosine* instead of *sine* on the opposite side; now $\frac{3}{2}\pi-\theta$, θ being less than a right angle, falls in the third right angle, and the sine in that right angle is —, so that $-\cos\theta$ must be written. The following results should be remembered:—

$$\sin\left(\frac{\pi}{2}-\theta\right)=\cos\theta,\ \cos\left(\frac{\pi}{2}-\theta\right)=\sin\theta,\ \tan\left(\frac{\pi}{2}-\theta\right)=\cot\theta;$$
$$\sin\left(\frac{\pi}{2}+\theta\right)=\cos\theta,\ \cos\left(\frac{\pi}{2}+\theta\right)=-\sin\theta,\ \tan\left(\frac{\pi}{2}+\theta\right)=-\cot\theta;$$
$$\sin(\pi-\theta)=\sin\theta,\ \cos(\pi-\theta)=-\cos\theta,\ \tan(\pi-\theta)=-\tan\theta;$$
$$\sin(\pi+\theta)=-\sin\theta,\ \cos(\pi+\theta)=-\cos\theta,\ \tan(\pi+\theta)=\tan\theta;$$
$$\sin(2\pi-\theta)=-\sin\theta,\ \cos(2\pi-\theta)=\cos\theta,\ \tan(2\pi-\theta)=-\tan\theta;$$
$$\sin(-\theta)=-\sin\theta,\ \cos(-\theta)=\cos\theta,\ \tan(-\theta)=-\tan\theta.$$

5. In the first revolution, θ and $\pi-\theta$ have the same sines and cosecants, θ and $2\pi-\theta$ the same cosines and secants, θ and $\pi+\theta$ the same tangents and cotangents.

6. $\sin\theta\operatorname{cosec}\theta=1$, $\cos\theta\sec\theta=1$, $\tan\theta\cot\theta=1$,

$$\frac{\sin\theta}{\cos\theta}=\tan\theta,\ \frac{\cos\theta}{\sin\theta}=\cot\theta.$$

7. $\sin^2\theta+\cos^2\theta=1$, $1+\tan^2\theta=\sec^2\theta$, $1+\cot^2\theta=\operatorname{cosec}^2\theta$.

$$\sin\theta=\frac{\tan\theta}{\sqrt{(1+\tan^2\theta)}},\ \cos\theta=\frac{1}{\sqrt{(1+\tan^2\theta)}}.$$

8. If $\tan\theta=\frac{a}{b}$, then $\sin\theta=\frac{a}{\sqrt{(a^2+b^2)}}$, $\cos\theta=\frac{b}{\sqrt{(a^2+b^2)}}$.

9. $\sin(\theta+\phi)=\sin\theta\cos\phi+\cos\theta\sin\phi$
$\sin(\theta-\phi)=\sin\theta\cos\phi-\cos\theta\sin\phi$
$\cos(\theta+\phi)=\cos\theta\cos\phi-\sin\theta\sin\phi$
$\cos(\theta-\phi)=\cos\theta\cos\phi+\sin\theta\sin\phi$.

10. $\tan(\theta+\phi)=\frac{\tan\theta+\tan\phi}{1-\tan\theta\tan\phi}$, $\tan(\theta-\phi)=\frac{\tan\theta-\tan\phi}{1+\tan\theta\tan\phi}$

11. $\sin\theta+\sin\phi=2\sin\frac{\theta+\phi}{2}\cos\frac{\theta-\phi}{2}$

$$\sin\theta-\sin\phi=2\cos\frac{\theta+\phi}{2}\sin\frac{\theta-\phi}{2}$$
$$\cos\theta+\cos\phi=2\cos\frac{\theta+\phi}{2}\cos\frac{\theta-\phi}{2}$$
$$\cos\theta-\cos\phi=-2\sin\frac{\theta+\phi}{2}\sin\frac{\theta-\phi}{2}.$$

12. $\sin 2\theta=2\sin\theta\cos\theta$
$\cos 2\theta=\cos^2\theta-\sin^2\theta=2\cos^2\theta-1=1-2\sin^2\theta$,
$\tan 2\theta=2\tan\theta\div(1-\tan^2\theta)$.

13. $1+\cos\theta=2\cos^2\frac{\theta}{2}$, $1+\sin\theta=2\cos^2\left(\frac{\pi}{4}-\frac{\theta}{2}\right)$

$$1-\cos\theta=2\sin^2\frac{\theta}{2},\ 1-\sin\theta=2\sin^2\left(\frac{\pi}{4}-\frac{\theta}{2}\right)$$
$$\frac{1-\cos\theta}{1+\cos\theta}=\tan^2\frac{\theta}{2},\ \frac{1-\sin\theta}{1+\sin\theta}=\tan^2\left(\frac{\pi}{4}-\frac{\theta}{2}\right)$$

14. $\frac{\sin\phi-\sin\theta}{\sin\phi+\sin\theta}=\frac{\tan\frac{1}{2}(\phi-\theta)}{\tan\frac{1}{2}(\phi+\theta)}$, $\frac{\sin\phi\pm\sin\theta}{\cos\phi+\cos\theta}=\tan\frac{1}{2}(\phi\pm\theta)$

15. If θ be half a right angle, or less,

$$\cos\theta=\tfrac{1}{2}\sqrt{(1+\sin 2\theta)}+\tfrac{1}{2}\sqrt{(1-\sin 2\theta)}$$
$$\sin\theta=\tfrac{1}{2}\sqrt{(1+\sin 2\theta)}-\tfrac{1}{2}\sqrt{(1-\sin 2\theta)}.$$

16. If n be any integer, and if $(\cos\theta+\sin\theta)^n$ be developed by the binomial theorem into $P_0+P_1+P_2+$ &c., P_0 being $\cos^n\theta$, P_1 being $n\cos^{n-1}\theta\sin\theta$, &c., then $\cos n\theta$ is $P_0-P_2+P_4-$ &c., and $\sin n\theta$ is $P_1-P_3+P_5-\ldots.$

17. Let C_n and S_n stand for the cosine and sine of $n\theta$

$$2\cos^2\theta=C_2+1$$
$$4\cos^3\theta=C_3+3C_1$$
$$8\cos^4\theta=C_4+4C_2+3$$
$$16\cos^5\theta=C_5+5C_3+10C_1$$
$$32\cos^6\theta=C_6+6C_4+15C_2+10$$
$$64\cos^7\theta=C_7+7C_5+21C_3+35C_1$$
$$128\cos^8\theta=C_8+8C_6+28C_4+56C_2+35$$
$$256\cos^9\theta=C_9+9C_7+36C_5+84C_3+126C_1$$
$$512\cos^{10}\theta=C_{10}+10C_8+45C_6+120C_4+210C_2+126$$

To change these into corresponding formulæ for powers of $\sin\theta$,

For	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	&c.
Write	S_1	$-C_2$	$-S_3$	C_4	S_5	$-C_6$	$-S_7$	C_8	&c.

Thus $16\sin^5\theta=S_5-3S_3+10S_1$
$32\sin^6\theta=-C_6+6C_4-15C_2+10$.

18. *De Moivre's Theorem* and its consequences:—

$$(\cos\theta+\sin\theta.\sqrt{-1})^n=\cos n\theta+\sin n\theta.\sqrt{-1}$$
$$\epsilon^{\theta\sqrt{-1}}=\cos\theta+\sin\theta.\sqrt{-1}\qquad\epsilon^{-\theta\sqrt{-1}}=\cos\theta-\sin\theta.\sqrt{-1}$$
$$\cos\theta=\frac{\epsilon^{\theta\sqrt{-1}}+\epsilon^{-\theta\sqrt{-1}}}{2}\qquad\sin\theta=\frac{\epsilon^{\theta\sqrt{-1}}-\epsilon^{-\theta\sqrt{-1}}}{2\sqrt{-1}}$$
$$\text{If } 2\cos\theta=x+\frac{1}{x},\quad\text{then } 2\sqrt{-1}.\sin\theta=x-\frac{1}{x}$$
$$\text{and } 2\cos n\theta=x^n+\frac{1}{x^n},\quad\text{and } 2\sqrt{-1}.\sin\theta=x^n-\frac{1}{x^n}.$$

The versed sine is little used and rarely mentioned in formulæ; and the coversed sine is really only invented for analogy's sake.

The term *sine* (the Latin word *sinus*, meaning the bosom) has been the object of much discussion. It was at one time looked on as a barbarism from the Arabic; and some endeavoured to substitute *semissis inscriptæ*, the half of the chord, for it. Others again thought that it was a corruption of *S. Ins.*, the abbreviation of the above. Dr. Hutton asserts that the Arabic word *Jeib*, which is used for the trigonometrical sine in that language, also means the bosom in common language; and we have been told that this is correct; if so, the Latin *sinus* is only the literal translation of the Arabic. The arc representing a bow (from which it gets its name), half of the string, which represents the sine of half the arc, would come against the breast of the archer. The versed sine (*sinus versus*, or turned sine) was called the *sagitta*, or arrow. The terms tangent and secant are derived in an obvious manner from the old definitions.

There is little of the history of trigonometry which can be either usefully or intelligibly separated from that of mathematics in general. Up to the middle of the last century it belonged rather to geometry than to algebra; and even in our own day algebraical trigonometry is not fully established in England, though rapidly making its way. Those to whom trigonometry is only useful as an instrument in the solution of triangles may enjoy the advantage of that specific clearness which geometry gives to the individual proposition in hand, without needing to feel the want of a system which points out the direction of future progress. But those who are to be trained in mathematics for higher views and more difficult applications, must acquire trigonometry in its most algebraical form as a constituent part of the language of algebra, and an element in every step of their future progress. It is worse than useless to attempt, for them, to draw a distinction between algebraical and trigonometrical; the science will now allow that distinction to remain, and will rather demand new modes of expression than dispense with any of the old ones.

There are those who feel sensible of incongruity in combining the fundamental notions of space and number together, and would rather, at any expense of trouble, keep them separate, except when they are formally united for any particular application. This feeling has our sympathy; and if it were possible to present a complete algebra, both in definitions and processes, without recourse to trigonometrical language, we should willingly agree to the separation. But hitherto it is not so; the only view of algebra in which there is nothing *impossible* is [ALGEBRA] essentially joined to space, and particularly to angular magnitude; so that those who would have a perfectly pure algebra must buy it at the expense of unexplained and apparently contradictory symbols.

It would be easy to avoid the notion of space while using the terms of trigonometry and its powerful formulæ. The series at the beginning of this article might be made the definitions of the sine and cosine; or $\sin x$ might be only an abbreviation of $x - \frac{1}{2\cdot3}x^2 + \&c.$, and $\cos x$ of $1 - \frac{1}{2}x^3 + \&c.$ The fundamental properties of the sine and cosine might without much difficulty be proved to belong to these series, without reference to any geometrical reasoning.

TRIMETHYLAMINE. [ORGANIC BASES.]

TRIMETHYLPHOSPHINE. [ORGANIC BASES. *Organic phosphorous bases.*]

TRINITRANISOL ($C_{14}H_5[NO_4]_3O_2$). A nitro-derivative of the phenate of methyl. [ANISOL.]

TRINITROCRESIC ACID. ($C_{14}H_5[NO_4]_3O_2$). An organic acid prepared by adding cresylic alcohol, drop by drop, to strong nitric acid. Its potash salt crystallises in orange needles.

TRINITRONAPHTHALIN. [NAPHTHALIC GROUP.]

TRINITROPHENIC ACID. [PHENYLIC GROUP; CARBAZOTIC ACID.]

TRINITY HOUSE. As the general management of the light-houses and buoys of the shores and rivers of England is entrusted to the Corporation of the Elder Brethren of the Holy and Undivided Trinity, generally known by the name of the Trinity House, it has been considered advisable to treat under the same head the special history of that corporation and the general discussion of the duties entrusted to their charge, as well as the discussion of the means usually adopted for lighting and buoying sea-coasts in general.

The objects it is desired to effect by those operations are, to indicate to mariners the precise position of sunken rocks, shoals, or sand-banks which may occur in the fair way of the navigation, and to mark the entrances of ports and harbours; and these objects must be effected in such a manner as that the more important indications should be visible by night as well as by day. Moreover, it is desired to indicate the navigable channel in passes or on shores during the daytime, when accumulations of alluvial matters, or sand-banks thrown up by tidal currents, or when bars at the mouths of rivers, render the navigation difficult or dangerous. The indications of the first class are usually given by light-houses, or by floating lights, visible from great distances; the indications of the second class are given by floating buoys, beacons, poles, or guides fixed in the beds of the channels. In all civilised countries the establishment of these indications is considered to be one of the most essential functions of the public authority; and the safety of commerce depends so greatly upon their perfection, that it is generally thought to be desirable to place them beyond the chances of irregularity attending private operations. Thus in England the Trinity House is charged with the performance of the necessary works for lighting and buoying the coast; in Scotland the Commissioners of the Northern Lights are so charged; and in Ireland the Ballast Board of Dublin has the control of the lights and buoys: all three being under the general superintendence of the Board of Trade. On the Continent, this branch of the public service forms part of the attributions of the minister of public works, and is usually centralised in his hands, in a far more distinct manner than it is in England.

The Trinity House appears to have been originally established in the reign of Henry VII., as an "association for piloting ships;" but it was only in 1680 that the Elder Brethren erected their first light-house, after several structures of that description had been built by private individuals under patents from the crown. The very irregular and unsatisfactory manner, and the very heavy charges entailed upon the commercial marine of England, by the unsystematic manner of lighting the coasts thus introduced, gave rise to so strong a spirit of opposition to its continuance, when the navigation of Europe had begun to revive after the peace of 1815, that numerous parliamentary inquiries have recently been made into the duties and functions of the Trinity House, and changes have been introduced in them from time to time. Thus the acts 3 Geo. IV. c. 3, 6 & 7 Will. IV. c. 79, 17 & 18 Vict. c. 104, have gradually led to the extinction of the private rights in light dues, and to the vesting of the whole of the duties of lighting and buoying the coasts in the authorities before described. The Trinity House in the meanwhile has maintained its original composition in all substantial matters; and it discharges at the present day the duties of superintending the pilotage of the English ports, concurrently with those of superintending the lighting and buoying, as well as of distributing the funds arising from certain light and pilotage dues, and from the sale of ballast (for which they have an exclusive patent in the port of London, with the exception of the Charlton pits), to certain charitable purposes specified in their original charter. The Trinity House consists of a master, a deputy master, nineteen acting elder brethren, eleven honorary elder brethren, and an unlimited number of younger brethren; in May, 1859, they numbered 178. The master and the honorary elder brethren have nothing to do with the practical operations of the House, and they are selected, solely on account of the eminence of their social positions, from the ministers of the crown or from amongst the higher aristocracy. The deputy master and the acting elder brethren are in fact self-elected from a list of the properly qualified younger brethren; and the qualifications for this purpose are,—that the candidates shall have attained the rank of commander in her majesty's navy for at least four years previously, or shall have served as master in the merchant service, on foreign voyages, for at least four years. The younger brethren are chosen from members of the royal navy, or from the commercial marine, and are admitted at the pleasure of the court of elder brethren upon the proposition of any one of those elder brothers. It may perhaps be as well to add, that subsequently to 1854 the Trinity House has abandoned its claim to the surplus of the light dues, which it had previously applied to charitable purposes. The act of parliament by means of which this expropriation of funds was effected also conferred upon the Trinity House general powers of supervision over the proceedings of the Commissioners of Northern Lights, and of the Irish Ballast Board, subject to the appellate jurisdiction of the Board of Trade.

The Board of the Trinity House discharges its duties by means of committees, and sub-committees for special purposes, whose proceedings, when necessary, are subject to confirmation by the general court. These committees are—1, the Treasury; 2, the Supervisors of the Ballast Department; 3, the Pilotage; 4, the Pilot Examination Committee; 5, the Lighthouse Committee; 6, the Pensioners; and 7, the House Affairs Committees. With the exception of the supervisors of the Ballasting Department, two in number, all these committees consist of four members; and the sub-committees named for special services may consist of any number of members at the option of the court, usually varying from two to four. The appointments are made annually, and the wardens are also elected annually, two going out every year; the master and the deputy master are usually elected during their lives, though they pass *pro forma* an annual election. The deputy master is *ex officio* chairman of all the committees. In scientific and technical matters the court is assisted by its engineer and an optician, those posts at the present day being occupied by Mr. J. Walker and Dr. Faraday. The members of the Trinity House divide among themselves the annual sum of 7000*l.*, and they employ a staff of clerks, messengers, &c., at their central office at an annual expense of about 6000*l.*; the salaries of the engineer and of the scientific adviser amount to 1700*l.*; so that the total cost of the central administration of the Trinity House is about 14,800*l.* per annum, for salaries, and for all miscellaneous expenses connected with the central board: it was, in 1857, about 17,285*l.* The gross income for the year 1857 was 268,646*l.* nearly, and the gross expenditure 204,013*l.*; for the year 1858 the gross income was 257,214*l.*, and the gross expenditure was 172,285*l.*: the surplus revenue is principally devoted to the extinction of the debt incurred, in pursuance of the act of 1846, for the purchase of the private interests in lighthouses.

The Commissioners for the Northern Lights were incorporated by act 38 Geo. III. c. 58, and they consist of 28 members, amongst whom are the lord advocate, the solicitor-general, the lords provosts and the elder bailies of the cities of Edinburgh and Glasgow, the provosts of Aberdeen, Inverness, Campbeltown, Dundee, and Greenock, and the sheriffs of the maritime counties of Scotland. The business of the commission is transacted in general meetings and in committee meetings; four of the former being held in the year, and of the latter there is usually one in every fortnight. The services of the members are gratuitous; in all technical and scientific matters they act under the advice of their engineers; and they have been fortunate enough to have secured for many years the services of the Messrs. Stevenson, who have done more to advance the science of lighthouse-building than any men since the days of Smeaton. The gross income of the commissioners for the years 1857 and 1858 was respectively 30,581*l.* and 26,865*l.*; whilst the gross expenditure was also respectively 62,204*l.* and 59,747*l.*, all in round numbers: from whence the deficiency was supplied does not distinctly appear in the published documents.

The Ballast Board of Dublin consists of 23 members, who are connected with the commerce of the country, but not necessarily, or even habitually, acquainted with the practical details of seamanship. The lord mayor of Dublin and the high sheriff of the city are annual *ex officio* members of the board. They manage their business by means of committees, thus arranged:—1, Library; 2, Lightship; 3, Inspection; 4, Accounts; 5, Lifeboat; 6, Harbour Bye-Laws; 7, Graving-Dock; 8, East Quay Wall Tax; 9, Pilotage Committees; and, whenever necessary, sub-committees for special purposes are appointed. The services of the members of the board are given gratuitously; the gross incomes for the years 1857 and 1858 being respectively 13,307*l.* and 15,710*l.* and the gross expenditure for the same years 58,768*l.* and 46,658*l.* It does not appear officially from whence the deficiency is supplied; but there can be little reason to doubt but that the money required for this purpose, as in the case of the deficiency of the Commissioners of the Northern Lights, is obtained from the Mercantile Marine Fund.

In addition to the lights and buoys maintained by the above enumerated public authorities, there are many others of perhaps a minor degree of importance, which are under the management of the local authorities, subject to the general control of the Trinity Board. Harbour lights, and the buoying of the entrances to docks, rivers, and navigable inland channels, are usually thus confided to the care of the local authorities interested in the navigation of the particular localities where those protections for shipping are placed.

It appears from the returns of the commissioners for inquiring into the subject of lighthouses, &c., published in 1861, that, at the end of 1859, there were the following numbers of lights, of the various kinds enumerated, around the coasts of Great Britain and Ireland :—

Country.	Lights on Shore.			Floating Lights.	Total.	Coast line in Miles.
	General.	Local.	Total.			
England . .	82	89	171	41	212	2405
Scotland .	46	67	113	1	114	4469
Ireland . .	69	4	73	5	78	2518
Totals .	197	160	357	47	404	9392

The Commissioners, however, observe that the immense number of islands, and deep bays, on the Scottish coast renders it difficult to make any accurate comparison between the efficiency of its mode of lighting, and that of other more regular coasts; but the table they insert of the distances apart of the lights in the United Kingdom and in France, has a considerable degree of interest. It seems that on the English coast there is 1 light on shore for 14 miles; on the Scottish coast, 1 for 39·5 miles; on the Irish coast, 1 for 34·5 miles; and on the French coast, 1 for 12·3 miles. The principle adopted by the French authorities in these matters is, that the lighthouses should be placed at such distances asunder as to allow their lights to cross one another, and to secure this condition with lighthouses of moderate elevation, it would appear to be necessary to adopt the average distance asunder of the French establishments. On a plain, easy shore, without rocks, or dangerous headlands, sunken reefs, or sand-banks, the distance apart, thus quoted, may be exceeded without inconvenience; but on dark nights it is difficult to distinguish a light at more than 15 miles distance, even when it is of the best construction, and at a great elevation above the sea level. In foggy weather, or during the fall of heavy rain, sleet, or snow, the range of visibility is, of course, considerably reduced. It is to be observed that if the English floating-lights be taken into account the distance asunder of the English lights does not exceed 11·37 miles.

The height to be given to a lighthouse must depend upon the distance to which its influence is required to extend. In order to keep the source of light on the level of the geometrical horizon at a distance of thirty miles, Mr. Airy says that a lighthouse ought to be 594 feet high, though the Cape St. Vincent light of 221 feet high, is stated in the report of the commissioners to be visible at that distance. It is seldom, however, that any necessity exists for so wide a range, and when light is diffused over so large an area, it can hardly be brilliant in any part thereof, unless at an immense cost. As a general rule, the horizon to be lighted is limited to about 15 or 20 miles, and the height of the lighthouses in such cases need not exceed from 110 to 220 feet above the sea level; as will be seen by an inspection of the table of lighthouses appended. The Eddystone lighthouse, which is built upon a solitary rock in the fairway of the British Channel, has a range of only nine miles, and the centre of the light is not more than 90 feet above low water line. In fact, the cost of erecting towers of this description in exposed situations is so great, that it is important to keep their height within the limits of the strict necessities of the respective localities. The average cost of a tower of about 110 or 120 feet high on the main land, or on rocky islands of comparatively easy access, is about from 4000*l.* to 10,000*l.*, including the illuminating apparatus; the cost of the more exposed towers is far greater, and some idea may be formed of the difficult and tedious nature of the works they involve from the outlay to which they give rise. Thus the Bell Rock lighthouse, on the east coast of Scotland, 117 feet high, cost 61,332*l.*, nearly; the Skerry Vore, on the west coast of Scotland, 158 feet high, cost 83,127*l.*; the Bishop's Rock, in the Scilly Isles, 145 feet high, cost 36,560*l.*; and the Phare de Bréhat, on the north-west coast of France, cost 38,800*l.*; but in this instance the expense of the engineer and the superintendents, and the cost of conveyance of materials, were not included. M. Reynaud, the engineer of this last-named tower, it may be added, dispensed with much of the complication of the joints of the courses of masonry introduced by Smeaton, and previously followed by other engineers; and he was thus enabled, not only to effect a considerable economy in the first outlay, but also to construct his tower more rapidly than his predecessors had done.

The floating lights are, as their name implies, fixed in vessels moored over or near to the danger it is desired to warn mariners to avoid. They are usually fixed at a height of from 20 to 45 feet above the sea level; and from that reason, as well as from the difficulty of introducing the best source of light (on account of the pitching and rolling of the ship in heavy seas), their range of visibility is not large. Practical authorities are still divided in opinion as to the best form of light vessels, and to the manner of mooring them; many persons, however, agree in recommending the adoption of a vessel built upon the principles of Herbert's circular buoys, moored from a central chain attached below the centre of gravity of the mass. Generally speaking, the light-vessels on the English shores are provided with gongs, which are sounded in foggy weather. The first cost of these vessels is, on the average, between 4000*l.* and 5000*l.*

Harbour lights are of every description, according to the importance of the harbour, and to the dangers of the navigable channel leading to it; sometimes they are exhibited from a small tower, sometimes from ordinary gas or oil lamps. It is rarely that the most expensive of these structures exceeds the cost of 400*l.* or 500*l.*; and the range of their illuminating powers is usually limited to two or three miles.

TABLE OF SOME OF THE MOST CELEBRATED LIGHTHOUSES.

Name.	Character of Apparatus.	Height.	Visible at	Cost.
ENGLAND.		Feet.	Miles.	£
Beachey Head .	1st class catoptric, revolving	185	22	
Start . . .	1st class dioptric, fixed	204	19	
Eddystone . . .	C. fixed	90	9	
Lizard	C.	232	20	
Scilly Bishop's . .	D.	110	18	36,559
St. Agnes . . .	C. revolving	183	16	
Lundy . . .	D. revolving	540	30	
Skerry Vore . . .	D.	150	20	83,126
North Foreland . .	C. fixed	184	18	
South Foreland . .	D. fixed	372	25	
Bell Rock . . .	D.	117	18	61,332
Flamborough . .	D. flash	103	19	
South Stack . .	C. flash	201	19	
Cromer	C. flash	274	22	
Calf of Man . .	C. flash	375	24	
Dungeness . . .	C. flash	92	14	
Girdleness . . .	?	100	19	11,000
FRANCE.				
Grisnez . . .	D. flash	194	23	
Ailly	D. revolving	305	27	
Fécamp . . .	D. flash	425	18	
Le Hêve . . .	D. fixed	397	20	
Barfleur . . .	D. revolving	236	22	19,600
La Hague . . .	D. fixed	157	18	13,200
Ushant . . .	D. flash	272	18	
Cordouan . . .	D. revolving	207	27	
Isle de Batz . .	D. revolving	223	24	4,320
Belle Isle . . .	D. revolving	276	27	
Calais . . .	D. fixed	167	20	7,479
Brêhat	D. fixed	136	22	38,800
Porquerolles . .	D. flash	262	20	19,880
COLONIAL AND FOREIGN.				
Cape St. Vincent . .	C. revolving	221	30	
Genoa . . .	? revolving	370	24	
Berlingas . . .	C. revolving	365	25	
Moro, Havana . .	D. flash	363	20	
Rocca, Lisbon . .	D. flash	598	30	
Bayona . . .	D. revolving	603	20	7,611
Gibraltar . . .	D. fixed	150	15	
Alexandria . .	? fixed	180	20	
Ceuta	D. fixed	483	23	
Coxo	D. revolving	370	24	
False Point, Bengal .	D. flash	70	13	
Pondichéry . . .	D. fixed	94	12	310?
St. Paul's, Canada .	? fixed	140	20	
Monte Video . .	? fixed	486	25	
Cape Ottoway . .	D. flash	72	13	
Highlands, N.Y. .	D. flash	72	13	
West Schouwen . .	D. revolving	166	22	6,400
Rundö . . .	D. ?	110	20	10,800
Westkappel . . .	D. fixed	145	22	
Terschelling . .	D. revolving	170	22	
Odessa . . .	D. fixed	208	23	
Tino (Spezzia) . .	D. fixed	389	24	
Villafranca . .	D. revolving	223	24	

The sources of light used are of several descriptions. In the large shore lights, mechanical lamps with three concentric wicks, or pump lamps, with four concentric wicks, and argand burners, are used; in floating-lights, the argand burners are alone used. The rays are concentrated and directed as may be required, either by means of *dioptric* lenses, by *catoptric* reflectors, or by a mixture of the two systems in the *cato-dioptric* apparatus; Mr. Thomas Stevenson has also introduced an apparatus he calls the *holophotal* one, which is in fact, nothing but a modification of the cato-dioptric light. In France, the dioptric lights are exclusively used: in England both the dioptric and the catoptric lights are used for the great land-towers, whilst the catoptric lights are exclusively used for floating-lights; and the harbour lights are usually made upon the holophotal system in the more important ports. Mariners are divided in their opinions as to the relative merits of these systems; but the tendency of opinion amongst scientific opticians is decidedly in favour of the dioptric one, with a central pump lamp of four concentric wicks. As to the distribution of the light, it may be either *fixed*, or *by flashes*, or *by intervals*, or again, it may be *white* or *coloured*, though the loss of light by the passage through a colouring medium constitutes a serious objection to the adoption of that system. In all cases where the light is not required in any particular direction, it is advisable to prevent its passage, and to reflect the rays, which would otherwise be dispersed, in the direction to be illuminated. Floating-lights, however, are very frequently made to show a red light; and there seem to be reasons for believing that it would be desirable to confine that colour to them, in order to distinguish the land from the floating lights; in which case it would perhaps be also desirable to make the harbour lights green, the essential condition being that no confusion should occur between contiguous lights. In the table given in col. 374 the description of the apparatus used in the various lighthouses is given, wherever it can be ascertained from published documents; and it may here suffice to refer the student who would investigate their respective merits to the Reports of the Commissions of 1846 and 1858; to a recently published reply to the second of these reports, under the title of 'Lighthouse Management;' and to Alan Stevenson's 'Elementary Treatise on Lighthouses.' The distances at which the several lights are stated as being visible, are, it must be observed, affected by the quality and character of the light, the height of the observer above the level of the sea, and the atmospheric refraction.

It may be added, that the cost of a large source of light, on either the dioptric, or the catoptric systems, is usually about 2000*l.*; and that the annual expense of maintenance, including oil, wicks, salaries, repairs of buildings, and of apparatus, ranges between 300*l.* and 400*l.* for a dioptric light, and between 350*l.* and 400*l.* for a catoptric light: the cost of maintaining a floating-light varies between 1200*l.* and 1300*l.* per annum, the crew consisting of a master, mate, two lamplighters, and seven seamen, of whom one-third are on shore at a time.

Of late years, the Mitchell's screw-piles [PILE ENGINE] have been very successfully applied for the purpose of supporting fixed lights on shoals in shallow water, and in comparatively-speaking protected positions; such as the beacon light at Fleetwood on the Wire, and the Maplin light at the mouth of the Thames. Wherever it would be possible so to do, these iron beacons should be substituted for the more unstable floating lights, for the oscillation of the latter must always impair their efficiency; and the pillar structures in the day time form more conspicuous beacons than the low hulls of the vessels can do. And here it may be as well to remark, that even lighthouse towers are of greater value for the purposes of navigation when they are constructed of materials which are of colours able to make them conspicuous objects by night as well as by day. The English lighthouses are usually painted white, or red; the lighthouse of Pondichéry, in the French East Indies, is painted in alternate vertical bands of white and black, a most efficient method of rendering it visible from a distance; the Scottish lighthouses are usually left of their natural colours, and are rarely distinguishable from the surrounding landscape in the day-time.

The buoyage of the shores of England would appear to be conducted in a very efficient manner, for there are no less than 1109 buoys in position upon those shores, without counting the wreck-buoys, or the warping-buoys at the entrances of ports, harbours, or docks. The Admiralty, as might naturally be expected, continue to use the old-fashioned nun and can buoys; but at Liverpool, and in the ports of active commerce, the Herbert's buoys are most generally used. These are made with wide circular bottoms, having a depression in the centre to which the eye for the mooring-chain is attached, so as to bring the centre of gravity as low as possible; their cost varies with their size, between 40*l.* and 90*l.* In consequence of the gradual growth of the buoyage system of England, there is great irregularity in the mode of colouring or marking them: in foreign countries the custom is, however, to paint the buoys respectively on the port and starboard sides of the channel of different colours, usually black and red; and though no doubt it would be preferable to adopt a uniformity of system in this respect, there would be a great amount of inconvenience in changing the colours of the buoys in any old-established line of navigation. It is worthy of remark that in the year 1858, not more than 4 per cent. of the buoys laid down by the public authorities of the United Kingdoms, broke from their moorings, whilst about 6 per cent. of those laid down by local authorities got adrift. In the portion of the Thames between London and the open sea, there are nearly seventy buoys, in addition to the light-ships, harbour-lights, fixed lights, and beacons; in the Mersey, the local authority connected with the port has established no less than 7 lighthouses, 8 floating-lights, 65 buoys, and 10 beacons; and indeed any one who may have had occasion to visit English and foreign ports, must be convinced that the buoyage of our shores is far more perfectly performed than that of any foreign ones.

Beacons are of every imaginable variety, from substantial stone pillars and iron structures on piles, to heaps of stones, poles with baskets at their heads, and to simple bushes or twigs; their cost varying from 10,000*l.* to a few shillings. There are above 200 structures of some importance, erected for the purpose of beacons, whose situations are indicated upon the Admiralty charts; and of course there are numerous smaller ones upon the banks of the rivers and navigable creeks of our shores. The only system which seems to prevail in the establishment and construction of these beacons, is that they should indicate, in a manner understood by the local pilots, the course of the navigable channel; and it would only be a pedantic affectation to seek to establish any general system in a service which essentially depends upon local necessities. The beacons on the respective sides of a navigable channel ought, however, to present some characteristic difference of colour or of outline.

It may be desirable to add that in England and Ireland the lamps of lighthouses are lighted from sunset to sunrise; in Scotland they are lighted at the commencement of the darkness and extinguished at dawn, in accordance with a calculated table. The regulation standard of consumption of oil in a first-class French dioptric apparatus is 785 gallons per annum; it would appear that in England the average consumption of all classes of lights is below this standard, whilst that of Scotland is above it.

As the arrangement of this article rendered it necessary to notice in the commencement the history and organisation of the Trinity House; and then, the practical details of the lighthouse system as now carried into execution; the history of lighthouses has been deferred to the conclusion. At a very early period in the history of commerce the necessity for such structures must have been felt, and the ancients paid very great attention to their construction. Originally the lights on the sea-shore were nothing but open fires on the ground; but by degrees lofty towers were substituted for these rude modes of illumination, and at last the lighthouses were treated as architectural monuments of the highest order. The recorded history of the Colossus of Rhodes would appear to be rather apocryphal; and the accounts handed to us of the Pharos of Alexandria are also of very doubtful authenticity; Josephus, however, states that its fire could be distinguished at 45 miles distance. This tower fell as recently as A.D. 1303, having been constructed by Ptolemy Philadelphus about B.C. 470. The Romans erected many lighthouses, and authentic records have come down to us of those of Ostia, Caprea, Ravenna, Puteoli, at the mouth of the Chrysorhoas, at the Bosphorus, at Boulogne, Dover, &c., both in the writings of historians, and in medals; and Pennant gives even a plate of a tower, supposed to have been a Roman light-house, which existed at Gaireg in Wales. The mode of illumination adopted in these cases seems to have been either an open wood or coal fire; or the combustion of torches dipped in tar; and in the most ancient of these structures, the irons for suspending the fire pots, or for holding the torches, may still be seen. During the Middle Ages towers were erected for similar purposes, of which remains may still occasionally be met with, and the tower of Genoa, a monument of the Renaissance period, may be referred to as a model of taste in such structures. The tower of Cordouan, at the mouth of the Garonne, was, however, the one which marked the most distinctly the revival of this class of monuments in modern time, and even at the present day it is worthy of careful examination by the engineer and architect. It was commenced in the reign of Henri II. of France, but no light was exhibited in it until the reign of Henri IV.; the style of architecture adopted is a very ornate style of Renaissance, as practised in France about the end of the 16th century.

Perhaps the turning point, so to speak, of the history of lighthouse building is to be found in the erection of Smeaton's celebrated Eddystone lighthouse, completed in the year 1759; for the success which attended the erection of that structure in so exposed a situation has led to the subsequent operations of the same kind throughout the world. Two attempts had previously been made to establish lights on this dangerous reef of rocks in the Channel; one by Winstanley, the other by Redyard; the structure erected by the former was washed away in the night of the 26th of November, 1703; and that erected by the latter was burnt on the 2nd of December, 1755. Smeaton was then applied to by the lessee; and he resolved to construct the new lighthouse of masonry, solid up to a certain height, in order to secure a sufficient resistance to the action of the sea by the dead weight of his structure, and thence hollow, to enclose the store and living rooms; the outline of his tower Smeaton copied from the outline of the bole of an oak tree, which he considered to be the best form to resist external violence from the winds and waves. Smeaton has recorded his own operations in a folio volume, published in 1791, entitled, "A Narrative of the Building of the Eddystone Lighthouse," to which the student is earnestly referred as to a model of a technical account of a most important work. From this it appears that the first stone was laid on the 12th of June, 1757, and that the light was first exhibited on the 16th of October, 1759: the light itself was obtained in Smeaton's time by the combustion of a great number of candles placed in metallic reflectors. Smeaton also erected an important lighthouse at Spurn Point, at the mouth of the Humber; but the grand principles of construction he introduced in the Eddystone were not again conspicuously applied, until the construction of the Start Point Lighthouse, between 1802 and 1806, under the direct orders of Mr. Stevenson, the engineer to the Commissioners of the Northern lights. Since the latter period the construction of lighthouses on the Bell Rock, the Skerry Vore, the Bishop's Rock, the Bréhat, Barfleur, la Hague, &c., has taken from the novelty of such structures, and rendered the public more indifferent to their merit; but they must always remain amongst the proudest triumphs of human skill and patience.

The use of oil lamps, instead of candles in lighthouses, is said to have been introduced by the celebrated hydrographical engineer, Borda, about 1780 or 1790; and the manufacture of the reflectors was greatly improved about the same time. The use of dioptric lights had been suggested to Smeaton in 1759, and they had actually been employed in the Portland lighthouse about 1789; but from some mismanagement they had fallen into disfavour until Augustin Fresnel, on 26th July, 1822, read a paper at the Académie des Sciences of Paris, describing a lighthouse apparatus on the dioptric system executed under his orders. In 1825 the French government undertook the comprehensive scheme for lighting their coast, which has since then been so carefully carried into execution; and as they began almost *de novo*, they have been able to adopt, throughout, the dioptric apparatus, whereas in the English lighthouses there were already numerous and costly catoptric lights of a very perfect nature in operation. The other nations of Europe have adopted the dioptric lights; and there seems to be little reason to question that the latter will ultimately replace the other known systems. The Fresnel's dioptric lamps may be popularly described as consisting of a mechanical, four-wicked, oil lamp placed in the centre of an octagonal glass prism; the centre part of each of the sides being formed of a plano-convex lens of about 15 inches in diameter, which is surrounded by a series of glass rings of a spherical triangular form, so as to produce the same effect upon the rays of light as the central lens does. Messrs. Leopold Fresnel, A. Stevenson, Arago and Faraday, have in turn contributed to the perfection of Augustin Fresnel's invention; and it is to the distinguished philosopher, Faraday, that we are indebted for the efficient means of ventilating the lamps of lighthouses now adopted—an apparently insignificant, but really a most important detail in their working.

The only other events of importance connected with the history of lighthouses, are the establishment of light vessels about the end of the last century; the erection of the screw-pile lighthouses and beacons, on Mitchell's plan, the first of the former erected on the Maplin sand, having been lighted for the first time on February 16, 1841; and the erection of the first cast-iron lighthouse at Morant Point, in Jamaica, under the orders of Mr. A. Gordon: it was lighted for the first time on November 1, 1841. Many valuable papers have from time to time been published on the scientific questions involved in this branch of the engineering art in addition to those previously noticed; amongst which attention is particularly called to the report by M. Rossel, 'Sur le Systême General d'Eclairage des Côtes'; to a mémoire by L. Fresnel in the 'Annales Des Ponts et Chaussées,' for 1831, on the stability of lofty towers; to another mémoire by the same author on the mode of treating the dioptric apparatus, in the 'Annales Maritimes et Coloniales,' 1836; and a description of the scaffolding and machinery used at the lighthouse at Bréhat, inserted by M. Potel in the 'Annales des Ponts et Chaussées,' for 1835.

It may be as well to add that the French authorities class the lights on their shores in four divisions, according to the power, and the range of visibility, of their lights. The "Phares" of the first class are visible from a distance of 30 miles; those of the second class, from a distance of 25 miles; those of the third class, from a distance of 15 miles; whilst the phares of the fourth class, or the harbour lights, are only visible at distances of about 6 miles. In addition to the harbour lights, the French authorities frequently place bells, with reflectors at the extremities of their piers; these bells are rung in foggy weather, but they are not considered to be of much service.

TRINODA NECESSITAS. This term, in Anglo-Saxon times, signified the three services due to the king in respect of tenures of lands in England for the repair of bridges, the building of fortresses, and expeditions against his enemies. All the lands within the realm were bound to contribute to these three emergencies, on the principle of their necessity for general convenience or safety; and for this reason every man's estate was subject to the *trinoda necessitas*, whatsoever other immunities he might enjoy. Even in royal grants to the Church of privileges and exemptions from secular services, the right of requiring contribution for these purposes was almost always reserved to the king. (Selden's *Janus Anglorum*, i. 42; Cowell's *Interpreter*, ad vocam.)

TRINOMIAL, the algebraical name for an expression which consists of three terms, as $a + b + c$, or $a x - b x^3 + b x^4$. [Term.]

TRIOXYPROTEIN. A substance said to be obtained from albuminous substances. Its existence is very problematical.

TRIPHOSPHETHYLAMINE. Synonymous with *triethylphosphine.* [Organic Bases. *Organic phosphorous bases.*]

TRIPLE ALLIANCE. [Treaties, Chronological Table of.]

TRIPLETS. [Doublets.]

TRIPLICATE. [Ratio.] In the common arithmetical sense, the triplicate of a given ratio is found by taking the cube of each of the terms of the ratio. Thus, when we say that two similarly formed solids, whose linear dimensions are as 4 to 7, are in the triplicate ratio of 4 to 7, it is meant that the bulks of those solids are in the ratio of 4 × 4 × 4 to 7 × 7 × 7, or of 64 to 343.

TRIPOD (*tripos, τρίπους*) is any article of furniture resting upon three feet, whence the name is given to tables, chairs, moveable altars, and other articles of the same kind. (Athen. ii. p. 49.) A chair or an altar of this kind must be understood when we read that the Pythia of Delphi gave her oracles from a tripod. We find also mention of tripods containing a certain measure of fluid (Hom., 'Il.,' xxiii. 264), and in this case we have to understand a bowl resting upon a pedestal with three feet. The crater, or the vessel in which the wine was mixed with water at the banquets of the ancients, was very frequently a tripod of this description.

The ancients made much more frequent use of tripods than we, and from their descriptions, as well as from the numerous representations of tripods on medals, and from the specimens still extant, we see that they were often most tastefully ornamented and of the most exquisite workmanship. They were usually of metal, but sometimes also of marble, and appear to have been made as much for mere ornament as for use. A tripod seems to have been at Athens a usual reward to a successful choragus. The tripod was connected with the worship of several gods, and was one of their attributes; but there is no deity in whose worship tripods occur so frequently as in that of Apollo. Accordingly the Pythia gave her responses from a tripod, tripods were the most common presents (donaria) to his temples, tripods were given to the victors in the games which were celebrated in honour of Apollo, and tripods appear on innumerable coins which have any relation to the worship of that god. Several fine tripods have been found at Pompeii. (Mazois, Donaldson.) In the accompanying cut of a bas-relief on an altar found in the forum at Pompeii an altar tripod is represented. Some tripods are preserved in the British Museum.

TRIPTYCH, an altar-piece in three divisions. As mentioned under Retable, altar-pieces were originally small and portable; they being carried with the other ecclesiastical utensils to the altar for the performance of the service, and removed at its conclusion. The altar-piece usually comprised a representation of some event in the history of Christ, or of an incident in the life of the saint to whom the altar was dedicated. In their oldest form, these portable altar-pieces seem to have consisted of two leaves or tablets of ivory or wood, like the larger two-leaved tablets carried by the Roman consuls and other superior officers, and like them they were called *Diptychs.* It is supposed that this in fact was their origin; the emperors having, when Christianity was recognised and protected, sent to the bishops, as to other high officers of the government, official diptychs, which, when they presided at the mass, were displayed open at the altar as the insignia of their office; but if so, the practice probably early fell into desuetude, and altar-pieces came to be commonly the gift of pious individuals or commissioned by wealthy communities, and they soon began to be made in various forms and of very different materials. The most frequent form was that of the *Triptych*, which consisted of a large central division, in which the principal circumstance was set forth, and two wings, fastened to the centre by hinges, so as when not in use to fold over it like shutters. On the insides of these wings were usually represented circumstances subsidiary to that shown in the central division, or portraits of saints or of the donors of the altar-piece, &c.; whilst on the outside was the Annunciation, the Baptism, or some event symbolising the initiation of the Christian religion, if the Crucifixion or other crowning event were shown inside; or, if the central picture related to a saint, the exterior was commonly made in some way correspondent. Sometimes there were more than three divisions, when it was called a *Polyptych.* Most frequently these portable altar-pieces are framed pictures; but they are very commonly, especially the earlier ones, bas-reliefs carved in wood or ivory. Often they are of inlaid-work, or marquetry, or of metal-work and enamel, the latter being sometimes richly inlaid with gems. Of all these kinds, and extending over a long range of years, there are many, and some very exquisite, examples in the South Kensington Museum, as well as of those large carved and painted triptych retables which so generally prevailed at a somewhat later date in Germany and the Low Countries. [Retable.] When the altar-piece came to be treated as an important architectural feature, and the paintings were much larger in size and more important in character, the triptych form was long retained, though, at least in Italy, the wings were no longer made to close over the centre, and certain supplementary parts were added. Of these, examples, either entire (as in that of Jacob Casentius) or portions (as those by Francia, Andrea Orcagna, &c.), may be seen in the National Gallery.

TRISECTION OF THE ANGLE. In the articles Duplication and Quadrature, we have given a slight outline of the history of two of those remarkable problems the solutions of which at one time engaged the attention of the learned, and have not yet ceased to be the ambition of a certain class of geometrical students. The trisection of the angle is the third problem of this kind.

The difficulty of cutting an angle into three equal parts is entirely of that geometrical nature which has been alluded to in the articles above cited. Euclid, who confines himself to the description of right lines and circles, could not by these only trisect an angle; but a very slight increase of descriptive power granted to pure geometry would overcome the difficulty entirely. In modern analysis there is no more trouble in trisecting an angle than in finding a cube root: the trigonometrical tables solve the question immediately to a certain number of places of decimals, and the calculation of a series and the solution of a cubic equation may be made to serve for any number of places of decimals. In order to show this, let a be the sine of a given angle, and x the sine of its third part: common trigonometry readily gives the equation—

$$3x-4x^3=a.$$

Now a can be found from the angle by means of the series for the sine; and the solution of the cubic equation is then easy enough. [INVOLUTION.] The three roots of the cubic equation are respectively the sines of the third part of the given angle, and of 120° and 240° more than that same third part. The cause of the geometrical difficulty is seen in the cubic equation, which, as appears above, is essential to the problem: no root of a cubic equation was ever exhibited by Euclid's geometry alone, unless that cubic equation were algebraically reducible to one of a lower degree, which could be solved without the extraction of cube roots.

The old geometers soon reduced the question to depend upon the following preliminaries. Let A, B, C, D be the sides of a rectangle, and E the diagonal passing through the junctions of B, C, and A, D: also let the angle E A be the one which is to be trisected. Through the point common to B, C, draw a line F passing through D and A produced, in such a manner that the part between D and A produced is twice E in length. Then it is easily shown that the angle F A is the third part of E A. Through the point C D draw an equilateral hyperbola, of which the asymptotes are A and B. A chord of this hyperbola, set off from C D towards A produced, and equal in length to twice E, will be a parallel to the line F required. Admit then the hyperbola among the curves of geometry, and the difficulty ceases. Again, if with two-thirds of any given line A as a major axis, an hyperbola be described whose asymptotes make an angle of 120°; and if with A as a base, and a point on the branch of the hyperbola adjacent to the single third of A as a vertex, a triangle be described, the larger of the angles adjacent to A will always be double of the smaller. Consequently, one of the external angles will be triple of one of its internal and opposite angles: so that by describing on the straight line A a segment of a circle containing the supplement of any given angle less than 180°, that circle will cut the branch of the hyperbola in a point which, being joined with the further extremity of A, will give an angle equal to the given angle.

Again, if from any point of a circle a straight line be drawn cutting the circle again, and then a diameter produced, in such manner that the portion externally intercepted between the diameter produced and the circle is equal to the radius, the angle formed by that line and the diameter produced is the third part of the angle made by the two radii, of which one passes through the first point of the circle mentioned, and the other is on the diameter which was produced. The construction can be effected by the CONCHOID of Nicomedes, which curve, if granted, gives the means of drawing a straight line of given length between any straight line and a curve, so that when produced it shall pass through a given point.

Either of the curves known by the name of QUADRATRIX may be made to trisect an angle, as obviously may any curve which assigns a straight line equal to a given arc: for a straight line may be easily trisected. The SPIRAL of Archimedes obviously gives another solution. But there is one particular curve known by the name of the *trisectrix*, which, among curves not geometrical, is peculiarly possessed of this property. It is one of the TROCHOIDAL curves having the deferent and epicycle equal, the motion in the latter being direct and equal to one-half of that in the epicycle. Or, add and subtract the radius of a circle from every one of the chords which passes through a point in its circumference, and the result will be a looped curve, which is the one in question. Let A be the point where the branches unite, and A B the axis of the loop: describe a circle with A as a centre, and A B as a radius; take a point P in the loop, and let A P and B P produced meet the circle in Q and R. Then the arc B R is three times B Q.

Many other modes of trisection have been proposed, some of great geometrical beauty; but the preceding are those to which it is most likely the student will meet with references in his reading. Many false trisections have also been proposed by persons who thought they could conquer the geometrical difficulty. There is not so much to expose in this class of trisections as in the one of quadratures of the circle which corresponds to it. There has never been so much of romance applied to this problem, no explanations of theological points have been made to arise out of it, no mode of converting the heathen asserted to be a necessary consequence, no Number of the Beast taken into the calculation. We shall only notice one false trisection, because it will afford a useful remark. In May, 1830, an Austrian officer announced his having obtained the geometrical solution in the 'United Service Journal,' and various comments appeared in that periodical, running through various months up to March, 1832. In January, 1832, an actual attempt at solution appeared, the work of a British officer then abroad. This at first sight appeared to be a *geometrical* solution; and what is more, it *was* a geometrical solution, and it might have cost a practised mathematician a moment's doubt whether the problem was not actually solved. But, owing to a mistake, a construction was made, which amounted to requiring that two sides of a certain triangle should be together equal to the third, the consequence of which was that the vertex of this triangle was brought down upon the base. Now the angle to be trisected was one of the angles at the base of this triangle, or *equal to nothing;* an angle which no geometer would refuse to declare capable of Euclidean division into three equal parts, each of course equal to nothing. Algebra generally furnishes some proof of the absurdity of the conditions of a problem when they contradict one another: but this is not the case with geometry. A latent assumption which restricts the generality of a solution always produces its effect in the former science; whereas in the latter such an assumption might be made part of a demonstration, and produce its consequences, without pointing out that those consequences are not true of the general figure which was drawn. The accurate use of the ruler and compasses will sometimes correct an error of this sort (and would have done so in the instance before us), *but not always:* solutions have been proposed before now which give so nearly the third part of an angle, that ordinary drawing will not serve to detect their falsehood. Any one who imagines he has discovered a geometrical trisection should take care to submit his construction to an algebraical verification; that is, if any person possessing algebra enough to do so should ever be in such a case.

TRISUCCINAMIDE ($N_2[C_8H_4O_4]_3$). An unimportant organic substance bearing the same relation to succinamide as triethylamine bears to ethylamine. [ORGANIC BASES.]

TRITHIONIC ACID. [SULPHUR.]

TRITYL. [PROPYL.]

TRITYLAMINE. [PROPYLAMINE.]

TRITYLENE. [PROPYLENE.]

TRITYL-SULPHURIC ACID. Synonymous with *Propyl-sulphuric acid.* [PROPYL.]

TRIUMPH (Triumphus) is in general a solemn procession for the purpose of celebrating a victory. Such processions and solemnities have been customary in all warlike nations, but they have never formed so prominent a feature in the history of a people as among the Romans. In a Roman triumph, the general who had gained a victory of sufficient importance to entitle him to this honour, entered the city of Rome in a chariot drawn by four horses; he was preceded by the captives and spoils, and followed by his army. The whole train passed along the Via Sacra up to the Capitol, where the general sacrificed a bull to Jupiter. Such a triumph was the highest honour that a military commander could look for; it was granted by the senate after any victory either by sea or by land, provided it was thought sufficiently important to deserve it.

When a general had gained a victory or had accomplished the object of his mission, he sent in a report to the senate, which then usually decreed a public thanksgiving (supplicatio.) The general returned to Rome, either with his army, or appointed a time when it was to meet him there; but he did not enter the city, and a meeting of the senate was held outside the walls, usually in the temple of Bellona, for the purpose of examining the general's claims to a triumph. The principal conditions upon which a triumph was granted, and which were established partly by custom, and partly by law, are as follows:—1. That the general should have held one of the great offices of the republic, that is, the dictatorship, consulship, or praetorship. 2. That he should have been invested with one of these offices at the time when he gained the victory, and that it should not have expired on the day of the triumph. This regulation however was set aside at an early period, and in cases where the term of office had expired the senate used to grant a "*prorogatio imperii,*" that is, a prolongation of his imperium or authority as general, for the day of the triumph. 3. That the victory should have been gained under the auspices and with the troops of the general who claimed a triumph. 4. That the advantages gained by the victory and the number of the enemies slain should come up to the amount prescribed by law. 5. That the victory should have been gained over a foreign enemy, and not in a civil war. 6. That the dominion of the Roman people should have been extended by the victory, and that it should not be a mere reparation of losses previously sustained. 7. That the war should be actually concluded by it, so as to enable the army to quit the enemy's country.

These rules however were not always strictly observed, and various deviations from them are recorded. Even the sanction of the senate ceased to be thought necessary as early as the fifth century before Christ, and the people in the Comitia Tributa assumed the right to grant triumphs (Liv., iii. 63; Dionys., xi. 50); and there are instances of generals triumphing in defiance of the senate and the people. In later times a general to whom a triumph in the city was refused, used to celebrate it on the Alban Mount. (Liv., xlii. 21.) If however the senate granted it, a sum of money was voted as a contribution towards defraying the expenses of the triumph, and the general was for the day of his triumph invested with the Imperium in the city. During the triumphal procession, the general, standing in his chariot, wore a purple toga embroidered with gold; his brow was adorned with a wreath of bay (laurus), and in his hand he carried a sceptre with the Roman eagle. On reaching the temple of Jupiter he deposited his wreath in the lap of the god. Banquets and other entertainments concluded the solemnity, which was generally brought to a close in one day, though in later times we meet with instances in which it lasted for three days. (Liv. xxxix. 52.)

During the time of the empire, the emperor himself, being the chief general of all the armies, was the only person that could claim a triumph, and it was rarely if ever granted to any one else but a member of the imperial family. Other generals received other compensations. All the triumphs that had been celebrated at Rome were carefully recorded in the Fasti triumphales, and their total number, from the earliest times down to the last, that of Belisarius over the Vandals, has been calculated to amount to 350.

A lesser kind of triumph was called *ovatio*, perhaps from "ovis," a sheep, which the general offered to Jupiter, instead of a bull. It was granted after victories which were not of sufficient importance to deserve the solemn triumph. The principal difference between the two was that in an ovation the general entered the city on foot, and in later times on horseback; he wore only the toga prætexta, and his brow was adorned with a wreath of myrtle. He carried no sceptre, and was frequently not accompanied by his army.

(O. Panvinius, *De Triumpho*, in Graevius, *Thesaurus Antiq. Rom.*, vol. ix.)

TRIU'MVIRI, or TRE'SVIRI, that is, "three men." A great number of offices at Rome, both ordinary and extraordinary (commissions) were held by three persons in conjunction, who thus formed a board which was intrusted with the management or administration of certain things. The office itself was called triumvirate (triumviratus). Extraordinary triumviri were appointed on various occasions and emergencies; for example, when a new colony was to be founded, the whole management of the business, together with the distribution of lands among the colonists, was usually intrusted to triumviri, whose full title was "triumviri coloniæ deducendæ," or "agro dividundo."

The triumvirate which has acquired the greatest celebrity in the history of Rome is that which was established towards the end of the republic by Octavianus, Antonius, and Lepidus. After the republic had been for years distracted by a series of civil wars, the three men mentioned above met near Mutina, in B.C. 43, and assumed, under the title of "triumviri reipublicæ constituendæ," the supreme power for five years, under the pretext of settling the affairs of the state. Their power and its duration was sanctioned by a senatus consultum. They so distributed the administration of the state among themselves, that Antonius received the greater part of Gaul; Lepidus, Spain and a small portion of Gaul; and Octavianus, Africa, together with the islands of Sicily and Sardinia. Lepidus was to govern Rome and Italy, while he exercised his power in Spain by proxy. His two colleagues endeavoured to get rid of the republican party by proscriptions, in which 2000 equites and 300 senators are said to have been put to death. Whole towns were robbed of their property, and their lands distributed among the veteran soldiers of the triumvirs, and hosts of people flocked around the standards of Brutus and other republican leaders, to escape an ignominious death. Consuls were elected during this period as before, but they were either the creatures and friends of the triumvirs, or one of the triumvirs himself held the consulship. In B.C. 38 the time of their office expired, and it was renewed for five years more without any opposition. About the end of this second term the secret enmity among the triumvirs burst out into open hostilities; a new civil war began, which ended in the destruction of republican freedom. The triumvirate of Octavianus, Antonius, and Lepidus is usually called the second triumvirate. The first triumvirate, if we may call it so, was merely a private coalition, or, as it is called in Livy's 'Epitome' (103), a conspiracy entered into by Cæsar, Pompeius, and Crassus, in B.C. 60: the title triumviri was perhaps never borne by them; it was certainly not recognised either by the senate or the people.

The triumviri who were regular magistrates belonged to the minor magistrates. Among them we shall mention, 1, the triumviri Capitales, who were instituted about the year B.C. 292, and were in many respects the successors of the quæstores parricidii. They inquired into capital offences, apprehended criminals and committed them to prison, wherever they discovered them, and also carried into effect the sentence passed upon them. 2, The triumviri Monetales, or the inspectors of the mint. 3, The triumviri Nocturni, whose duty it was to superintend the watchmen in the city at night, and to prevent or put out fires in the city.

TROCHAIC VERSE, a kind of verse used by the Greek and Latin poets, especially by the tragedians and comedians. The foot from which it takes its name and of which it principally consists is the trochee (— ⏑), which is combined, like the iambus and anapæst, into *metres* of two feet each. The most common form of the Trochaic verse is that which is composed of a perfect dimeter followed by a dimeter wanting the last half-foot. This form of verse is the 'Trochaic Tetrameter Catalectic' of the Greeks, which was also called by the Romans *quadratus*, from its containing four metres, and *septenarius*, from its containing seven complete feet. The following is an example in English:—

Alexánder háted thínking,
  Dránk aroúnd the coúncil bóard,
Hé subdúed the wórld by drínking,
  Móre than bý his cónquering swórd.

In the Greek tragedians the following are admitted as variations on the pure Trochaic verse:—

1. The syllable at the end of the line may be short, since its time is filled up to that of a long syllable by the slight pause which occurs in that place.
2. The trochee may be resolved into a tribrach (⏑ ⏑ ⏑) in any place; but the final long syllable may not be resolved into two short ones.
3. A spondee (— —) may be substituted for the trochee in the second place of each metre, that is, the *even* places of the verse (2nd, 4th, and 6th).
4. The spondee may be resolved into an anapæst (⏑ ⏑ —). But
5. If there is a tribrach in the seventh place, neither a spondee nor an anapæst is allowed in the sixth.
6. A dactyl (— ⏑ ⏑) is allowed, but only in a *proper name*, in any place.

The following table represents the different forms of the verse:—

	1.	2.	3.	4.	5.	6.	7.	8.
	— ⏑	— ⏑	— ⏑	— ⏑	— ⏑	— ⏑	— ⏑	⏑
	⏑ ⏑ ⏑	⏑ ⏑ ⏑	⏑ ⏑ ⏑	⏑ ⏑ ⏑	⏑ ⏑ ⏑	⏑ ⏑ ⏑	⏑ ⏑ ⏑	—
		— —		— —		— —		
		⏑ ⏑ —		⏑ ⏑ —		⏑ ⏑ —		
P.N.	— ⏑ ⏑	— ⏑ ⏑	— ⏑ ⏑	— ⏑	— ⏑ ⏑	— ⏑ ⏑	— ⏑ ⏑	

The first dimeter ought to end at the end of a word. Often also each metre, and sometimes each foot, ends at the end of a word. If the first metre ends with a word after which there is a slight pause or break in the sense, then the second foot of the first metre is a trochee or tribrach, not a spondee or anapæst. The same restriction applies to the sixth foot when it ends with a word followed by a slight break in the sense. These niceties of structure are exemplified in the following lines:—

Phœn. 636. 'Ως ἄτιμος, | οἰκτρὰ πάσχων, ἐξελαύνομαι χθονός.
——— 646. 'Ελπίδες δ' οὔπω καθεύδουσ' αἷς πέποιθα | σὺν θεοῖς.

The comic tetrameter resembles the tragic in every respect, except that sometimes, though very rarely, a tribrach in the seventh place is preceded by a spondee in the sixth, and that the niceties of structure just mentioned are not always observed.

The points of difference between the Greek and Latin trochaic verse are similar to those which exist in the iambic verse, and are explained in the article TERENTIAN METRES. The chief point to be attended to is, that in Plautus and Terence a spondee which has the accent, or *ictus metricus*, on the first syllable, is allowed to stand for a trochee in any place except the seventh. The following line is from Terence:—

Numquam cuíquam nóstrum vérbum fécit néque id ægré tulit.

The *ictus metricus* of the trochaic tetrameter, both in tragedy and comedy, is as follows (according to the notation used in the article ARSIS):—

′ \ ″ \ ′ \ ″ \ ′ \ ″ \ ′ \ ″

that is, the *arsis* falls on the first syllable of each foot, and of the two *arses* in each metre the second is the stronger.

The trochaic verse is rapid in its movement, and is generally used where stronger emotions are expressed than in the ordinary iambic trimeter. It is, however, closely connected in rhythm with the iambic verse. If we prefix to the trochaic tetrameter catalectic an introductory short syllable, we obtain an iambic tetrameter: if from the trochaic tetrameter catalectic we cut off the first foot and a half, we have the iambic trimeter; and it must be observed that these results are not only true with respect to quantity, but that the licences and restrictions of the trochaic verse become, by thus altering the order of scansion, the very licences and restrictions of the iambic verse. Thus the *spondee in the even* places of the trochaic verse, the *anapæst* in the *fourth* and *sixth* places, the *dactyl* of a proper name, and the *want of a cæsura* between the two dimeters, produce respectively, in the iambic trimeter which we get by cutting off the beginning of the trochaic tetrameter, the *spondee in the odd* places, the *dactyl* in the *first* and *third* places, the *anapæst* of proper names, and the *penthemimeral cæsura*. The resemblance of rhythm is also seen by dividing each verse at its chief pause, namely, the end of the first dimeter in the trochaic, and the penthemimeral cæsura in the iambic, when it is found that the second portions of the two are identical in every respect; and it is in fact by these concluding portions that the rhythm of a verse is determined.

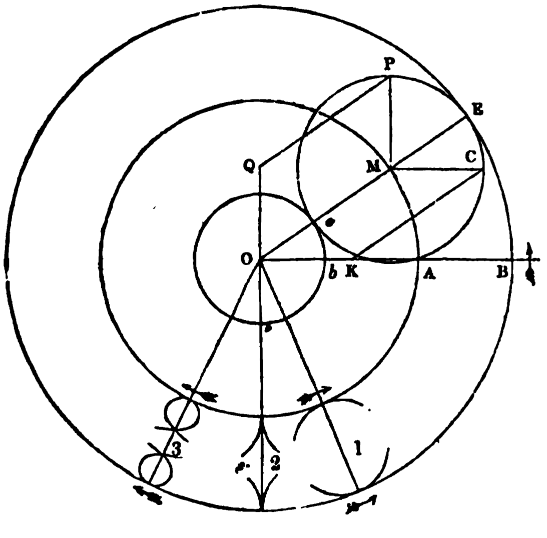
Troch. — ⏑ — ⏑ — ⏑ — ⏑ | — ⏑ — ⏑ — ⏑ —
Iamb. ⏑ — ⏑ — ⏑ | — ⏑ — ⏑ — ⏑ —

Further particulars respecting the tetrameter catalectic, and an account of other trochaic metres, will be found in Tate's 'Introduction to the principal Greek Tragic and Comic Metres,' and Hermann's 'Elementa Doctrinæ Metricæ.'

TROCHOIDAL CURVES. Under this term are included all lines produced by the composition of two circular motions, including the straight line, the circle, the ellipse, a class of curves called epitrochoids, of which one particular case is called the epicycloid, and a class called hypotrochoids, of which one particular case is the hypocloid. Among these must also be included the extreme case in which one of the motions is rectilinear, which gives the common trochoid, the cycloid, and a class of spirals which includes the involute of the circle, the spiral of Archimedes, and others.

There are two ways of considering these curves. The first, which is universally adopted, may properly be called the *trochoidal* mode (τροχος, a hoop), because in it one circle is made to roll like a hoop, either upon a straight line, or upon the circumference of another circle. The second, which we believe might be advantageously substituted for the first, we shall propose to call the *planetary* mode, because it resembles the consideration of the manner in which a planet and its satellite move round the sun. Here a circle, without any rolling, has its centre carried round the circumference of another. As there is no elementary work which treats of these combined motions, though some understanding of them is necessary even for the purposes of the most elementary astronomy, we shall first enter into this subject at more length than usual, endeavouring to make ourselves understood by those who have the first notions of geometry and of the composition of motion: we shall then, more briefly, consider the application of the differential calculus.

Fig. 1.



Let the point M (*fig.* 1) be carried uniformly round the circumference of the circle A M, and let M be the centre of a circle whose radius is M O (=A B). Let a point P be carried about the moving circle, so that its angular velocity from a line of fixed direction in the moving circle (say M C parallel to A B) always bears a given proportion to the angular velocity of M, say that of $n : 1$; that is, when the line O M has described the angle A O M, the line M P has described the angle C M P, which is n times A O M. It has been supposed that when M was at A, P was at B. The point P will describe a curve which is one of those called *trochoidal;* or, on this explanation, *planetary*. And the circle C P being always contained between two fixed circles, B E and $b\,e$, the planetary curve is always contained between those two circles. We shall now propose a nomenclature for the principal parts of this system.

As in the Ptolemaic mode of considering the planets, let the fixed circle A M be called the *deferent*, the moving circle C P the *epicycle*. Let M be the *mean point*, P the *planet*, O the *centre*, and let the planet be said to be in its *apocentre* or *pericentre*, when it is farthest from, or nearest to, the centre. And as every apocentre must lie on B E, and every pericentre on $b\,e$, let these circles be called respectively apocentral and pericentral. Let O P, as usual, be called the radius of the curve, or its *radius vector;* and the angle A O P its *vectorial angle*. When the revolution is in the direction from A to M, let it be called *direct;* when in the contrary direction, *retrograde*. Let angle A O M be called the *mean* or *deferential angle*, and denoted by ϕ; and let C M P be called the *epicyclic angle*, being denoted of course by $n\phi$. Let the angle contained between the pericentral and apocentral radii be called the *angle of descent*. The following theorems will be readily seen, as soon as these terms are understood:—

1. The planetary curve beginning from its apocentre at B, and the epicyclic motion being direct, and greater than the mean motion, there will be a pericentre as soon as C M P has gained two right angles upon C M E or A O M,—that is, when $n\phi-\phi=180°$, or ϕ is 180° divided by $n-1$.

2. But if the epicyclic angular motion, being still direct, be less than the mean motion, so that C M E is greater than C M P, there will be a pericentre when C M E has gained two right angles upon C M P, or when $\phi-n\phi=180°$, or ϕ is 180° divided by $(1-n)$.

3. And if the epicyclic motion be retrograde, so that P begins to move the other way from C, there will be a pericentre when C M E and C M P together make two right angles, or when $\phi+n\phi=180°$, or when ϕ is 180° divided by $1+n$.

4. When the planet has come to its pericentre, it will begin immediately to ascend towards the next apocentre, in a curve of the same form as that by which it descended, but inverted in position, the parts preceding and following the pericentre being alike, and the part preceding the next apocentre resembling that following the last apocentre. As soon as the second apocentre is gained, the curve will start again, in the same manner as the first. If n be a commensurable number, say $p \div q$, where p and q are integers, and the fraction be in its lowest terms, the curve will return into itself when M has completed q revolutions: there will be, if the epicycle be direct, $p-q$ or $q-p$ apocentres, and as many pericentres; but if the epicycle be retrograde, there will be $p+q$ apocentres, and as many pericentres. But if n be incommensurable, the convolutions will go on for ever, and the curve will never be completed. We have therefore, in order to obtain the form of the curve, only to consider one descent from apocentre to pericentre, or one ascent from pericentre to apocentre: though the general appearance of the curve depends much on the effect of many convolutions.

5. Every planetary curve may be described by two distinct epicyclic motions. For if we describe the parallelogram O M P Q, we see that the point Q describes a fixed circle equal to the epicycle, while Q P is the radius of a moving circle equal to the deferent. If then the radius of the deferent be a, that of the epicycle b, and the epicyclic angular velocity be n times the deferential or mean velocity, it gives the same planetary curve as if the radius of the deferent were b, that of the epicycle a, and the epicyclic velocity $1 : n$th of the deferential. If, then, we take the epicycle to be the least of the two, we do not limit our investigation, provided we consider every possible case of epicyclic velocity.

The actual motion of the planet, compounded of both motions, deferential and epicyclic, may be either direct or retrograde; and the curves may be best classified by observing whether the motions at the pericentres and apocentres are direct, retrograde, or neither. At 1 is represented a case of each motion, pericentral and apocentral, direct; at 2, a case of each motion, when it is neither direct nor retrograde—that is, directly towards the centre; at 3, a case of each motion, retrograde. We shall now consider how to make the separation of these cases.

First, as to the apocentres. When the motion in the epicycle is direct (for abbreviation say when the epicycle is direct), the two motions conspire; the line M C, then at A B, is being carried forward with the velocity of A, while P is being carried from M C. Let angles be measured in theoretical units [ANGLE], and let the deferential or mean velocity be 1, then the linear velocity of A is a, and that of P, when at B, is the linear velocity to an angular velocity n and radius b, or nb. Consequently, $a+nb$ is the apocentral velocity, which is direct; or the apocentral velocity is always direct when the epicycle is direct. But if the epicycle be retrograde, the line M C is advancing with the velocity a, while P is receding from it with the velocity nb. Consequently, when the epicycle is retrograde, the apocentral velocity is direct, neither, or retrograde, according as a is greater than, equal to, or less than, nb.

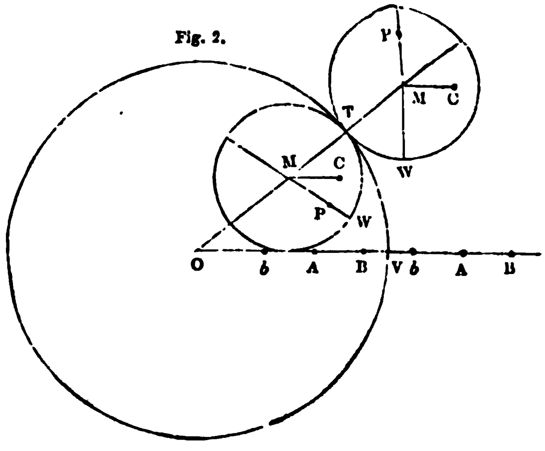
Next, as to the pericentres. We can make a pericentre by supposing the planet to be at b when M C is on A B. Now, if the epicycle be direct [MOTION, DIRECTION OF], the line B b being carried forward with the velocity a, the planet is carried backwards with the velocity nb. Consequently, when the epicycle is direct, the pericentral motion is direct, neither, or retrograde, according as a is greater than, equal to, or less than, nb. But when the epicycle is retrograde, the motion of the planet at b, as well as that of b B, is in advance, and $a+nb$ represents the whole velocity: consequently, when the epicycle is retrograde, the pericentral motion is always direct. Observe that we name the deferential motion with respect to the centre, and the epicyclic motion with respect to the centre of the epicycle: as explained in the article cited, a motion may be direct with respect to one, and retrograde with respect to the other.

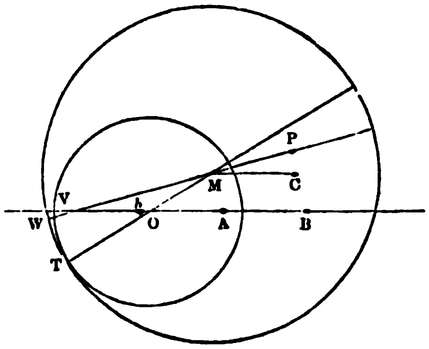
We shall now consider the trochoidal mode of viewing the subject, previously to combining the two. Let the circumference of one circle roll upon that of another, any point on, inside, or outside of the rolling circle (if outside, of course supposed to be fixed to it by a carrying arm) describes a curve by the motion compounded of the motion of the rolling circle round its own centre, and the motion of that centre round the centre of the fixed circle. Three cases may be supposed, as in the following diagrams (*fig.* 2). The two convexities may be opposed, that is, the rolling circle may roll outside the other; or the concavity of one may fit the convexity of the other. This last divides into two cases: first, when the rolling circle is the smaller, in which case it rolls entirely inside the other; next, when the rolling circle is the larger, in which case the fixed circle is always inside the other. Now each of these cases may easily be reduced to a much more intelligible planetary system, by which much of their difficulty will be removed. It should be observed, that when the convexities are opposed, the trochoidal system is called *epi*-trochoidal, and when concavity fits convexity, *hypo*-trochoidal. We call the radius of the fixed circle F, and of the rolling circle R.

1. Every epitrochoidal system is a planetary system in which the epicycle is direct. Taking the circle which rolls entirely outside the

other, P is the point describing the curve, and TW has rolled over TV since P was at B. Now OM is constant, being $F+R$; so that, since P

Fig. 2.





rolls uniformly round M, here is a planetary system in which OM is the radius of the deferent, MP that of the epicycle (which is direct), and the epicyclic velocity is to the deferential as the angle CMP to AOM. Now the arcs TW and TV are equal, whence AOT being ϕ, and TMW being ψ, we have $F\phi=R\psi$, or

$$CMP=\left(\frac{F}{R}+1\right)\phi;\text{ so that }\frac{F+R}{R}\text{ is the ratio of the velocities.}$$

Hence, looking at the double generation of every planetary system, we have either

$$a=F+R,\ b=MP,\ n=\frac{F+R}{R};$$

$$\text{or } a=MP,\ b=F+R,\ n=\frac{R}{F+R}.$$

2. Every hypotrochoidal system in which the rolling circle is the larger of the two is a planetary system in which the epicycle is direct. Here, in the proper diagram, WT has rolled over VT, as before, OM and MP are the radii of the deferent and epicycle, and the epicyclic velocity is to the deferential as the angles CMP and AOM; and $OM=R-F$. If AOM and TMW be ϕ and ψ, we have, from the equal arcs TW and TV, $R\psi=F\phi$, and

$$\angle CMP=\phi-\psi=\left(1-\frac{F}{R}\right)\phi;\text{ whence }\frac{R-F}{R}\text{ is the ratio of the velocities.}$$

We have then either

$$a=R-F,\ b=MP,\ n=\frac{R-F}{R};$$

$$\text{or } a=MP,\ b=R-F,\ n=\frac{R}{R-F}.$$

3. Every hypotrochoidal system in which the rolling circle is the smaller is a planetary system in which the epicycle is retrograde. In the proper figure it is now evident enough that OM, the radius of the deferent, is $F-R$; and that AOM and WMT being ϕ and ψ, we have $R\psi=F\phi$, from the equal arcs TV and TW. It is plain also that MP, the radius of the epicycle, moves with a retrograde velocity. Moreover, the epicyclic and deferential velocities are as the angles CMP and AOM, and ($R\psi$ being $=F\phi$)

$$\angle CMP=\psi-\phi=\left(\frac{F}{R}-1\right)\phi,\text{ and }\frac{F-R}{R}\text{ for the ratio of the velocities.}$$

Either then

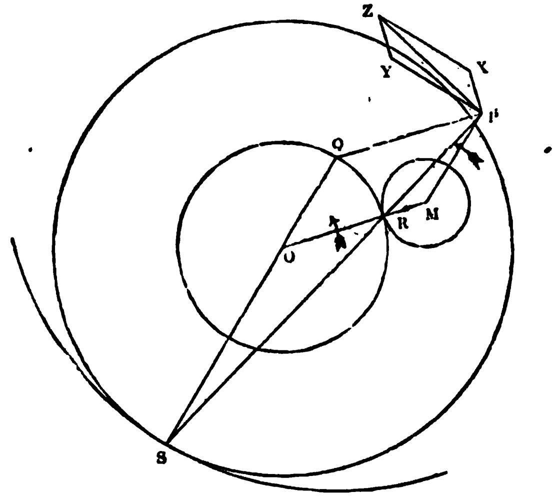
$$a=F-R,\ b=MP,\ n=\frac{F-R}{R};$$

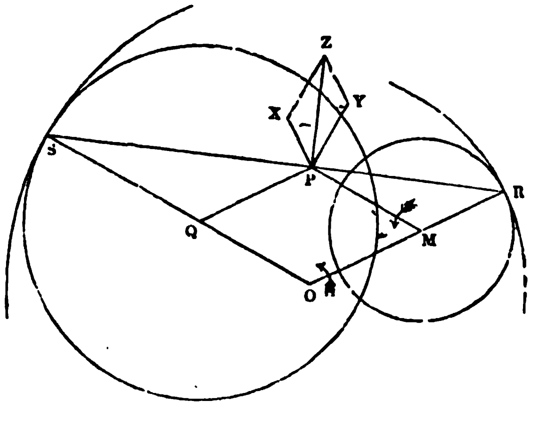
$$\text{or } a=MP,\ b=F-R,\ n=\frac{R}{F-R}.$$

To distinguish the two hypotrochoidal systems, which have very different properties, let that one in which the rolling circle is smaller than the fixed, so that the curve lies entirely inside the fixed circle, be called the *internal* hypotrochoidal system; and that in which the rolling circle always contains the fixed circle, and in which the curve is entirely without the fixed circle, the *external* hypotrochoidal system. It appears then that a planetary system with a direct epicycle belongs to both the epitrochoid and the external hypotrochoid; while one with a retrograde epicycle belongs to the internal hypotrochoid.

We now take the converse problem—namely, given a planetary system, to find the corresponding trochoidal systems. This might be easily done algebraically from the preceding results, but a simple geometrical construction will much assist the beginner, who rarely can get the true phase of a figure out of formulæ. It is required first to construct the real velocity and direction of a planet at any point of its curve. The epicycle is, at any given instant, moving forward perpendicularly to the radius of the deferent with the velocity a, while the planet is moving perpendicularly to the radius of the epicycle with a velocity nb. The composition of these two velocities gives the real motion and direction of motion of the planet for the time being, and shows us how to draw the tangent of its curve.

Fig. 3.





Let OM and MP (*fig.* 3) be radii of the deferent and epicycle (not drawn); and from P, the planet, draw PX and PY perpendicular to OM and MP. Make PX to PY as a to nb, and complete the parallelogram PXYZ. Then PX represents the motion, for the instant, of the whole epicycle, and PY the motion of the planet in the epicycle; whence PZ represents the planet's actual velocity, and PZ is tangent to its curve. In the first of the figures the epicyclic motion is direct, and in the second retrograde, the arrows showing the direct motion of revolution. Also, for variety, the planet is placed much nearer to its pericentre in the second figure than in the first.

Draw PRS perpendicular to PZ, meeting OQ and OM in S and R. Then, the sides of the triangles QPS, PMR, being severally perpendicular to those of P Z X, these three triangles are similar to one another. Hence

$$\text{PQ}\,(=a) : \text{QS} :: \text{PX} : \text{XZ} :: a : nb, \text{ or } \text{QS} = nb$$

$$\text{PM}\,(=b) : \text{MR} :: \text{ZX} : \text{XP} :: nb : a, \text{ or } \text{MR} = \frac{a}{n}.$$

In the second figure, or when the epicycle is retrograde, it will always be found that R and S are in O M and O Q produced; but the first figure, as drawn, is good only for the case in which n is greater than 1, as was supposed in the construction, and is seen in the result, since Q S (or nb) is greater than Q O (or b), and R M (or $a : n$) is less than O M (or a). If n had been less than 1, P S would have passed through O Q; but in all cases of direct epicycle, one of the sides O M and M Q is cut externally and the other internally; while in every case of retrograde epicycle, both are cut externally. We have then

$$\text{Epicycle retrograde} \begin{cases} \text{OS} = b\,(1+n), & \text{QS} = bn \\ \text{OR} = a\left(1+\frac{1}{n}\right), & \text{MR} = \frac{a}{n} \end{cases}$$

$$\text{Epicycle direct} \begin{cases} n > 1 \begin{cases} \text{OS} = b\,(n-1), & \text{QS} = bn \\ \text{OR} = a\left(1-\frac{1}{n}\right), & \text{MR} = \frac{a}{n} \end{cases} \\ n < 1 \begin{cases} \text{OS} = b\,(1-n), & \text{QS} = bn \\ \text{OR} = a\left(\frac{1}{n}-1\right), & \text{QS} = \frac{a}{n} \end{cases} \end{cases}$$

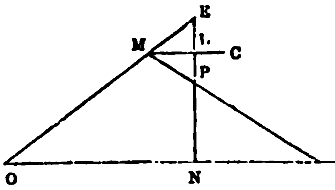
We can now immediately show that every planetary curve can be trochoidally described in two ways, it being already known that every trochoidal curve can be planetarily described in two ways. It appears that O R and O S are the same for every position of the planet in a given system, since they depend only on a, b, and n. Consequently, while the planet moves, R and S revolve in circles about O; and if we now pass to a trochoidal system in which O R is the radius of the fixed, and M R of the revolving circle, the point P, connected with the revolving circle by the arm M P, will describe a trochoidal curve which is identical with the planetary curve, from the elements of which its circles were obtained. Or O S may be made the radius of the fixed circle, and Q S of the revolving circle, the arm of connection being Q P. For instance, if we take the retrograde epicycle, and make

$$\text{F} = b\,(1+n),\ \text{R} = bn;\ \text{then } b = \text{F} - \text{R}\ \ n = \frac{\text{R}}{\text{F}-\text{R}},$$

which are the equations, already found, of connection between the internal hypotrochoidal system and its corresponding planetary one; and similarly for the other cases. And the result is, as appears from the figure, that every direct-epicycle planetary system is both epitrochoidal and externally hypotrochoidal, while every retrograde-epicycle planetary system is in two different ways internally trochoidal. We are thus enabled to refer the description of all the trochoidal curves to their corresponding planetary systems, which are much more easily followed, especially when, as is always in our power, we make the radius of the epicycle not exceeding that of the deferent. It has appeared that when $a = bn$, the planet has no motion of revolution, at the apocentre in a retrograde epicycle, and at the pericentre in a direct epicycle; the motion must then at those epochs be all from or to the centre, giving curves with such cusps as are shown in a former diagram. Now, looking at the corresponding trochoidal systems, we see that when $a = nb$, Q S = Q P, and M R = M P, or the point which describes the trochoid is *on the circumference of the rolling circle*. In this case the epitrochoid is called an epicycloid, and the hypotrochoid an hypocycloid. And since in all cases the line which joins P with the point of contact of the circles (R or S) is normal to the curve, or perpendicular to the tangent, it follows that in the epicycloid and hypocycloid, the two chords which join the point that traces out the curve with the two extremities of the central diameter of the rolling circle are, one tangent, and the other normal, to the curve.

We shall now pass on to the consideration of the varieties which planetary curves offer; and first we have to separate some extreme or critical cases from the rest. These are when $n = 1$, 0, or -1, for we shall now begin to distinguish direct from retrograde epicyclic motion by making n negative in the latter case. When $n = 1$, P (*fig.* 1) will be always in the continuation of O M, either at E or e, as it was first placed; consequently the planetary curve is here only the apocentral or pericentral circle of other cases. If $n = 0$, P will always coincide with C; now C describes a circle equal to the deferent, but having its centre at K, O K being equal to the radius of the epicycle. If $n = -1$, the angle C M P (*fig.* 4) is always equal to M O N, and the triangles E O N, C M P, are similar; whence E P, or twice L P, is always a given proportion of E N, the ordinate of a circle: it follows, then, that the planetary curve is an ellipse when $n = -1$. But when $a = b$, the point P is always at H, in the line O H, and the planetary curve is as much of the straight line O H as extends from twice O M on one side to twice O M on the other. Looking at the trochoidal character of these varieties, we have, when $n = 1$, either $\text{F} = 0$, $\text{R} = b$, or $\text{F} = 0$, $\text{R} = a$; that is, the curve then described is made by a circle revolving round a point in its circumference; in both cases we have a circle. But when $n = 0$, we have $\text{F} = b$, $\text{R} = 0$, or the trochoidal curve belongs to a point connected with a circle of no radius, which revolves on a circle of the radius b, or O K. This is one of those extreme cases which are rather interpreted than perceived [INTERPRETATION]: if a circle of no radius revolve from K, it can never make any progress, and the arm, K C, which carries the moving point, is always describing a circle. It is the extreme case of the following supposition:—Let a circle of extremely small radius revolve on the circle of radius O K, carrying with it the arm K C; it will make but little progress on the larger circle in many revolutions, during which C will describe many nearly circular folds very close to each other. Lastly, when $n = 1$ retrograde, we have $\text{F} = 2b$, $\text{R} = b$, or the fixed circle has twice the radius of the rolling circle. When $a = b$, the point which describes the curve is on the circumference of the rolling circle; and thus we have the following theorem:—When a circle rolls inside another of double its diameter, every point attached to that circle, internally or externally, describes an ellipse; but every point on the circumference of the rolling circle describes a straight line, the extreme limit of an ellipse.

Fig. 4.



Since we can always suppose the lesser of the two circles to be the epicycle, and the greater the deferent, when there is a lesser and a greater, there is yet another extreme case in which the epicycle and deferent are equal, so that all the pericentres are in the centre O itself, for now the epicycle always passes through that centre. This case will be best considered after the several other cases of which it is the extreme. We now go on to the general question, namely, having an epicycle less than the deferent, and having both radii given, required the forms of all the varieties of the planetary curve which arise from giving different values to n.

We may recapitulate the formulæ first given with their algebraical character, as follows:—The radius of the deferent is a, that of the epicycle b, the ratio of the angular velocity of the planet in the epicycle to that of the epicycle round the deferent is n, which is negative when the epicycle is retrograde. The angle moved through by the centre of the epicycle since the last epoch when the planet was at its apocentre being ϕ, that moved through by the planet round the epicycle in the same time is $n\phi$, and when the planet has come to its pericentre, ϕ is $180° \div (n-1)$, this meaning, when positive, that the radius of the epicycle has gained 180° in direction upon that of the deferent; and, when negative, that the radius of the deferent has gained 180° upon that of the epicycle. And the apocentral velocity of the planet is $a + nb$, n having its proper sign, its absolute revolution round the centre being direct or retrograde, according as $a + nb$ is positive or negative. The pericentral velocity is $a - nb$, to be interpreted in the same manner. In the corresponding trochoidal systems, F and R being the radii of the fixed and rolling circles, and C the length of the arm which carries the moving point, measured from the centre of the rolling circle to which it is attached, we have either

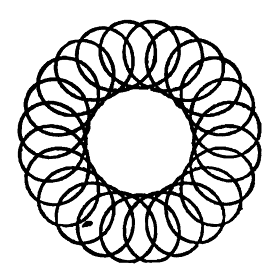
$$\text{F} = b\,(1-n),\ \text{R} = bn,\ \text{C} = a,\ \text{ or } \text{F} = a\left(1-\frac{1}{n}\right),\ \text{R} = \frac{a}{n},\ \text{C} = b,$$

where n is to have its proper sign, and

F positive, R positive, denotes an epitrochoidal system;
F negative, R positive . . . . external hypotrochoidal system
F positive, R negative . . . . internal hypotrochoidal system;

or, in fact, that circle only which sees the concavity of the other, is to have its radius counted as negative. This is an induction from the various previous cases, such as the student of algebra will readily make.

I. *When* n *diminishes from a great value down to* a ÷ b. Let us first suppose n very great and positive, so that the angle from apocentre



to pericentre is small, the apocentral revolution direct, the pericentral retrograde. Passing to the trochoidal systems, both circles are large in the external hypo-system; and the fixed circle nearly equal to the deferent, and the rolling circle small, in the epi-system; also the planet is far within the circumference of the rolling circle in the external hypo-system, and far without it in the epi-system. All this must be collected from the formulæ. The curve is then of the foregoing form.

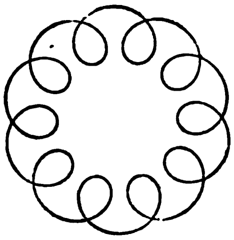
The angle during which the revolution of the planet is absolutely retrograde is always thus found:—Determine ϕ_1 from the equation

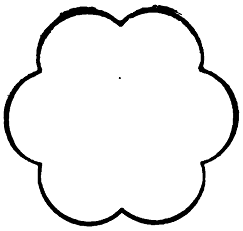
$$\cos (n-1)\phi_1 = -\frac{a^2+b^2n}{ab(1+n)},$$

which can always be done if the second side be less than unity. Then the retrogradation begins when $\phi=\phi_1$, and ends when

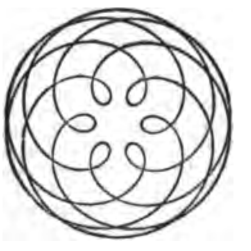
$$\phi = \frac{360^\circ}{n-1} - \phi_1.$$

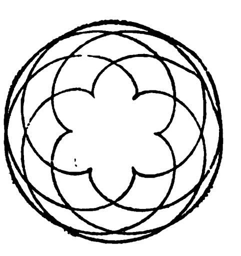
As n diminishes, the angle from apocentre to pericentre increases; the radii of both circles in the external hypotrochoidal system diminish; in the epitrochoidal system the fixed circle grows less, and the revolving one greater, both the circumferences approaching the planet. When n grows small enough, being still so large that $a < nb$, the loops cease to interlace, and become separately visible. This goes on until n is so far reduced in value that $a = nb$, when the pericentral velocity vanishes, both the trochoidal systems have the planet upon the rolling circle, the loops degenerate into cusps, and we have epicycloids, as follows:—





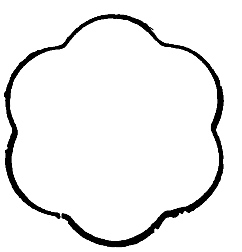
Towards the end of this division the character of the curve may be much affected by the relative value of b and a. At the epicycloid, when $n=a\div b$, the angle from apocentre to pericentre, as subtended at the centre, is $180^\circ \div (n-1)$ or $180\ b \div (a-b)$ in degrees. The nearer $a \div b$ is to unity the greater does this angle become, and if a be near enough to b, it may be increased to any amount: so that a planet might descend from apocentre to pericentre through thousands of thousands of revolutions before it formed its loop or cusp, and began to ascend, as in the following figures:—





If a be actually equal to b, all these curves have the lower points of their loops in the centre itself, but as n diminishes down to unity, the descent becomes slower and slower; and when $n=a\div b$, or 1, ceases altogether, the apocentral circle itself being the hypocycloid of this extreme case.

II. *When* n *diminishes from* a÷b *down to* 1. When n has become a little less than $a\div b$, the angle from apocentre to pericentre has increased, the velocities at both places are direct, or the planet is never retrograde. In the trochoidal systems, it is now without the rolling circle of the external hypo-system, but within that of the epi-system. The cusps have given way to points of contrary flexure, as in the following figure:—



The way to find these points of contrary flexure is as follows:—Find ϕ_2 from the equation;

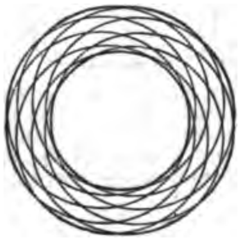
$$\cos (n-1)\phi_2 = -\frac{a^2+b^2n^3}{abn(n+1)};$$

then there is one point of contrary flexure when $\phi=\phi_2$; and another when

$$\phi=\frac{360^\circ}{n-1}-\phi_2$$

As n diminishes, these points of flexure, after approaching somewhat towards the apocentre, cease that approach, and begin to return towards the pericentre, in which they are lost when n has come down to the square root of $a\div b$. But this time they do not unite in the cusp from which they came, but the convex part of the curve disappears, in such a manner as to give a remarkable straightness to the parts adjoining the pericentres.

When n is less than $\sqrt{(a\div b)}$ the curve is always convex, and the angle from apocentre to pericentre perpetually increasing, the descent may be made as slow as we please, as in the following:—

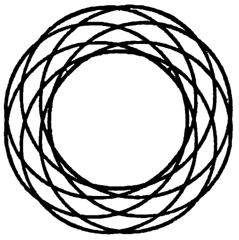


At the limit of this case, when n becomes 1, all descent ceases, and the apocentral or pericentral circle is all that is left, as before described.

At the beginning of this section of curves, the planet was upon the rolling circle in both trochoidal systems: it immediately passes outside the rolling circle in the external hypo-system, and inside the rolling circle in the epi-system. Moreover, in the former the fixed circle gets smaller, and the rolling circle approaches the epicycle, so that when $n=1$, the external hypo-system is merely the epicycle revolving round a point in its circumference. But in the latter, as n approaches to 1, the rolling circle approaches the deferent in size, while the fixed circle becomes smaller and smaller: its extreme case coincides with the extreme case of the former system.

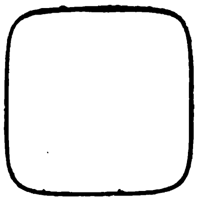
III. *When* n *diminishes from* 1 *to* 0. The angle from apocentre to pericentre, or the angle of descent, as we may call it, which left off infinite at the end of the last section, immediately becomes very great and negative when n is a little less than 1; indicating that the descent is performed by the radius of the deferent gaining upon that of the epicycle, instead of the contrary. The curve is always concave to the centre, and at first, in its long folds, much resembles that of the last diagram. But as n diminishes towards 0, the angle of descent becomes less and less, and is only -180° when $n=0$; and during this time, the descent becomes more and more circular, until, when $n=0$, we have nothing but the circle with centre K and radius KB, as before explained (*fig.* 1). As to the trochoidal systems, the external hypo-system and the epi-system have changed formulæ: in the latter, the fixed radius changes from 0 to b, and the rolling radius from b to 0, the planet being always outside the rolling circle: the extreme case has already been explained. But in the former system both radii increase without limit, and become infinite when $n=0$, the planet being always within the rolling circle. The extreme case must be thus explained [INFINITE]: to construct a planetary curve in which the epicyclic motion is very slow compared with the deferential, by means of its external hypo-trochoidal system, we must take both radii, fixed and rolling, very large, and the larger the slower the relative epicyclic motion without limit.

IV. *When* n *increases negatively from* 0 *to* -1. The angle of descent, which left off at -180°, now diminishes in amount, being still negative; and by the time $n=-1$, it brings us, as we have seen, to an ellipse, which gives -90°. The apocentral and pericentral velocities are still positive throughout this section, and the curve is a series of shorter concave descents. The final ellipse has $a+b$ and $a-b$ for the semi-axes.

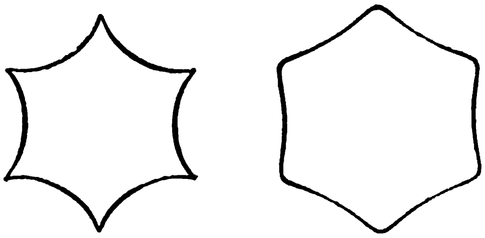


Both the trochoidal systems are internal hypo-systems, the planet being inside the larger of the rolling circles, and outside the smaller. At the extreme case, the ellipse, the two systems are the same, and in both cases the fixed circle becomes double of the rolling circle in diameter. Before the extreme case, the greater rolling circle belongs to the greater fixed circle, and the less to the less.

V. *When* n *increases negatively from* -1 *to* $-$a : b. Something resembling the last continues (the angle of descent still diminishing) until that angle is too small to allow of a descent wholly concave. By the time n becomes $-\sqrt{(a \div b)}$ the descent is almost a straight line, except very near the apocentre, and when n is greater than $\sqrt{(a \div b)}$, taken negatively, there are points of contrary flexure dividing the convex from the concave part as before.

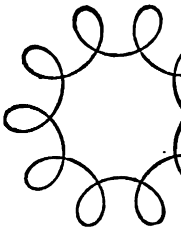


These points of contrary flexure do not, as before, return to the pericentre at which they begin; but as n varies from $-\sqrt{(a \div b)}$ to $-a \div b$, they run up the arc of the curve, and unite at the apocentre, when $n=-b \div a$, in a cusp. This cuspidated curve is the hypocycloid, and up to this point both apocentral and pericentral motions are direct.

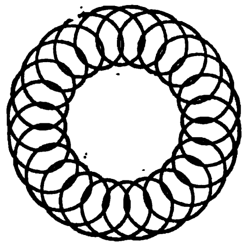


The only change that has taken place during this time in the trochoidal systems is a continual increase of both circles in one of them, and a continual diminution of both in the other. At the hypocycloid both the rolling circles are thus brought to pass through the planet, and the fixed circles become equal. The common radius of the fixed circles is $a+b$, those of the rolling circles are a and b.

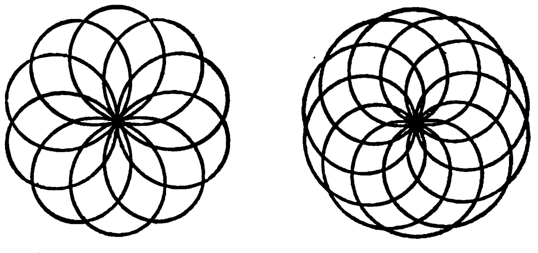
VI. *When* n *increases negatively from* $-$a : b. We left off with the hypocycloid at which the apocentral motion (in revolution) is nothing. This apocentral motion afterwards becomes retrograde, the pericentral continuing direct, so that apocentral loops begin to be formed; and the central angle of retrogradation, in which the planet passes through the higher part of a loop, may be found from a preceding formula.



As n increases, these loops become nearer and nearer, and at last begin to interlace, the angle of descent continually diminishing. In the trochoidal systems, both circles of one of the hypo-systems increase without limit with n, while in the other the fixed circle perpetually becomes more nearly equal to the deferent, while the rolling circle diminishes without limit. As n increases, each of the loops more and more nearly coincides with the epicycle, and the extreme limit is a circle of *no radius*, carrying the planet on an arm equal to the radius of the epicycle, and revolving on a circle equal to the deferent: or a revolution in an epicycle whose centre is fixed. This limit of course is never attained; or perhaps the analyst would say, that when n is infinite, the planet goes over the whole space between the apocentral and pericentral circles.

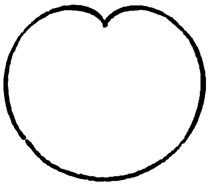


When the deferent and epicycle are equal, or $a=b$, the epicycloid becomes the apocentral circle, and the hypocycloid the straight line. The other curves take various extreme forms, as in the following diagrams:—



There is never any sensible arc of retrogradation; all the retrogradation, as it were, taking place suddenly at the pericentre, that is, at the centre. We shall leave the further investigation of these cases to the student.

When $n=2$, the angle of descent is always 180°, and the epicycloid has the rolling and fixed trochoidal circles equal, and is a curve shaped somewhat like a heart, whence it is called the *cardioide*.



On these curves generally we may remark, that their minor modifications of form are very various. The descent through a point of contrary flexure, for example, gives two curves of very different figures, according as the angle of descent is more or less than a right angle; and the loops may be made very small or very large, compared with the rest of the curve. It must be particularly noticed also, that by the angle of descent we mean simply the angle between the apocentral and pericentral distances, not the vectorial angle described in going from one to the other: the latter may become greater than this angle of descent before the pericentre is arrived at, and then diminish down to the angle of descent.

Let us now suppose the deferent to become a straight line, or $a=\infty$, and let the centre of the epicycle be carried along this line with a velocity a, while the planet moves in the epicycle with an angular velocity ν in theoretical units. Curves will now be described which are called *trochoids*, among which the CYCLOID has the same place as the epicycloid among the epitrochoids, or the hypocycloid among the hypotrochoids. The forms can be readily imagined by conceiving the deferent to be a circle of great radius. It is now of no consequence whether the epicyclic motion be direct or retrograde. If ν be very great, we have a series of interlacing loops; when ν becomes less, these loops separate; when $a=\nu b$, the loops degenerate into cusps, and we have the cycloid; and when a is greater than νb we have only a series of undulations with points of contrary flexure. All this may be represented by a trochoidal system in which a circle rolls upon a straight line, carrying with it an arm to which the planet is attached; and the trochoid is looped, cycloidal, or wavy, according as the planet is without, on, or within, the rolling circle. It will be a good exercise for the student to deduce the centre and radius of the rolling circle from a construction similar to that hereinbefore employed for deducing the elements of the trochoidal from those of the planetary system.

The diagram in MOTION, col. 796, exemplifies the three species of trochoids.

To suppose the epicycle infinite leads to nothing: but if we now take a trochoidal system, and suppose the rolling circle infinite, we have what is equivalent to a straight line rolling round a circle to which it is always tangent, and carrying a planet at the end of an arm which is supposed fixed to the straight line. If the planet be on the straight line, we have obviously the INVOLUTE of a circle; for the unrolling thread described in the article cited may be considered as the part of the rolling tangent which has been in contact with the circle since the beginning of the motion. If the planet can pass through the centre of the fixed circle, the curve becomes the spiral of Archimedes. These spirals must be made complete by using both positive and negative values of the radius vector. [SPIRAL.] They are not of much use except to the mathematician.

The various classes of trochoidal curves must be studied to aid in forming a proper conception of the effect of combined circular motions: one remarkable instance of their application is that of the apparent motions of the planets. These *apparent* motions must be exactly what would take place if the earth were at rest, the sun revolving in an orbit about the earth, which orbit is the deferent; while the sun itself is the centre of an epicycle equal to that of the planet's orbit, in which epicycle the planet moves. And since the epicycle and deferent are convertible, we may in the case of one of the superior planets use the planet's larger orbit as a deferent, and the sun's smaller orbit as an epicycle. Again, since the planet of the smaller orbit always has the greater angular velocity, the ratio of the epicyclic to the deferential velocity, or n, is always, the smaller orbit being the epicycle, greater than unity. Hence, when the planet is retrograde, the loop of its apparent orbit is always turned towards the earth, so that the apparent magnitude of the planet is always greatest in the middle of its retrogradation. To test these things, we ought to have angles of longitude measured in the plane of the planet's orbit; but since the inclinations of those planes to the ecliptic are not very great (with the exception of the new planets), angles measured on the ecliptic, or longitudes commonly so called, will do as well for illustration.

When the planet begins and ends its retrogradation, the tangent of the apparent orbit passes through the earth, and the planet, moving in that tangent, does not sensibly change its apparent position in the heavens for several days: it is then called *stationary*. The angle between these two stationary points is the angle of retrogradation, for which a formula has been given. But we shall simply notice the general figure of the apparent orbits, giving the ratio of the radius of the deferent to that of the epicycle, when the smaller of the two orbits (sun's round the earth, and planet's round the sun) is the epicycle, and the larger the deferent, and also the ratio of the angular motions.

	$a \div b$	n		$a \div b$	n
Mercury . .	2·58	4·15	Jupiter .	5·20	11·86
Venus . .	1·38	1·63	Saturn . .	9·54	28·78
Mars . .	1·52	1·88	Uranus .	19·18	84·01
Small . .	2·4	3·6			
Planets to	2·8	to 4·6			

All these must belong to looped curves, going round for ever, and never reuniting, in consequence of the practical incommensurability of the values of n. The angles of the descent are—for Mercury, $180° \div (4·15-1)$ or 57°; for Venus, 286°; for Mars, 205°; for the small planets, from 70° to 50°; for Jupiter, 16°; for Saturn, 6½°: for Uranus, 2½°. The doubles of these angles will be the angular distances between the lower points of two loops. Thus, to construct the orbit of Mercury, take a deferent of which the radius is about 2½ times that of the epicycle, draw the apocentral and pericentral circles, lay down a succession of radii each at 57° to the preceding, draw the ascents and descents in the manner of the figure in § I., and the result will give a sufficient idea of the orbit for mental purposes. The time of the planet moving from the lower part of one loop to that of the next is, roughly, a revolution in the epicycle; that is, a year of the inferior planet for each inferior planet, and a year of the earth for each superior planet.

In the case of the moon we have a the radius of the earth's orbit, b that of the moon round the earth, $a \div b$ is about 400 and n is about 13; whence, since 13 is less than $\sqrt{400}$, or 20, the moon's real orbit round the sun has neither loops nor flexures, but is always concave to the sun. [MOON.]

The mathematical part of this subject labours under the same disadvantage as the more popular explanation, namely, the adoption of the trochoidal mode of viewing the curves, which, though it gives really the same equations as the planetary mode, embarrasses the question by introducing more complicated formulæ. If we take the line drawn from the centre to an *apocentre* of the curve for the *positive part* of the axis of x, and as before, let ϕ be the deferential angle, $n\phi$ the epicylic angle, x and y the rectangular co-ordinates of a point in the curve, r and θ the polar co-ordinates, a and b the radii of the deferent and epicycle, we have (1)

$$x = a\cos\phi + b\cos n\phi, \quad y = a\sin\phi + b\sin n\phi$$

which are the fundamental equations of the curve. Here a and b are both positive, ϕ (and also θ) vanishes at the apocentre, which is on the positive side of the axis of x, and n has its proper sign. But if we place a pericentre on the positive side of the axis of x, other things remaining the same, we have (2)

$$x = a\cos\phi - b\cos n\phi, \quad y = a\sin\phi - b\sin n\phi.$$

If the last terms stand thus, (3)

$$x = a\cos\phi \pm b\cos n\phi, \quad y = a\sin\phi \mp \sin n\phi$$

they may be reduced to (4)

$$x = a\cos\phi \pm b\cos(-n\phi), \quad y = a\sin\phi \pm b\sin(-n\phi)$$

or the case is one of the preceding, the ratio of the velocities being $-n$ and not n. If the first terms be negative, change the signs of x and y, and let the curve thus found make a half revolution; but if the first terms differ in sign, the equation is reduced to one of the preceding cases by changing the sign of ϕ (and of n, if necessary), which shows that what we had was the equation to the curve as described by a contrary motion of the deferent. All this, however, has only reference to the reduction of a particular equation to the form (1), which we shall use throughout. From (1) we readily find

$$r^2 = a^2 + b^2 + 2ab\cos(n-1)\phi \quad . \quad . \quad (5)$$

or the passage from apocentre to pericentre, or from $r = a+b$ to $r = a-b$, is performed, while $\cos(n-1)\phi$ changes from 1 to -1, or $\overline{n-1}\,\phi$ from 0 to π, or to $-\pi$, according as n is $>$ or $<$ 1. We also have

$$\tan\theta = \frac{a\sin\phi + b\sin n\phi}{a\cos\phi + b\cos n\phi} \quad . \quad . \quad . \quad . \quad (6)$$

To determine the period of retrogradation, if any, we must differentiate the preceding, which gives

$$r^2\frac{d\theta}{d\phi} = a^2 + b^2 n + ab(1+n)\cos(n-1)\phi \quad . \quad . \quad . \quad (7)$$

and there is retrogradation when the second side is negative, from whence the formula already given is deduced, and the condition that nb must be numerically greater than a (a being throughout supposed greater than b). The following formula will help to obtain this condition:—

$$\left\{\frac{a^2 + b^2 n}{ab(1+n)}\right\}^2 = 1 - \frac{(a^2 - b^2)(n^2 b^2 - a^2)}{a^2 b^2 (1+n)^2} \quad . \quad . \quad . \quad (8)$$

From the preceding formula (7), it is easy to obtain $\frac{1}{2}\int r^2 d\theta$, the area included between two radii and the curve. But this is subject to the interpretation of that part of the area which is contained between two radial tangents to a loop, and the lower part of the loop being negative: the total result of which is that the area inside the loop is counted twice, and all the rest once.

To find the arc and points of contrary flexure we must deduce the following equations (9, 10):—

$$\frac{dx^2}{d\phi^2} + \frac{dy^2}{d\phi^2} = a^2 + b^2 n^2 + 2abn\cos(n-1)\phi$$

$$\frac{dx}{d\phi}\frac{d^2y}{d\phi^2} - \frac{dy}{d\phi}\frac{d^2x}{d\phi^2} = a^2 + b^2 n^3 + ab(n^2+n)\cos(n-1)\phi$$

The second formula changes sign at the points of contrary flexure, whence the criterion before given is determined, by help of the following (11):—

$$\left\{\frac{a^2 + b^2 n^3}{ab(n^2+n)}\right\}^2 = 1 + \frac{(b^2 n^2 - a^2)(b^2 n^4 - a^2)}{a^2 b^2 (n^2+n)^2}.$$

The various double points are thus determined. Let ϕ and ϕ' be the two deferential angles belonging to a double point, the first when the curve passes through it the first time, and the second for the second. Since the value of r is the same at points, we have $\cos(n-1)\phi = \cos(n-1)\phi'$, whence we have

$$(n-1)\phi' = 2k\pi \pm (n-1)\phi \quad . \quad . \quad (12)$$

k being a whole number, positive or negative. If $\pi \div (n-1)$, the angle of descent, be called μ, we have $\phi' = 2k\mu \pm \phi$; and if we substitute this in the equations (1) remembering that $n\mu = \pi + \mu$, we find, by ordinary trigonometrical development, that the following equations exist between the co-ordinates of every double point:

$$x = \cos 2k\mu \,.\, x \mp \sin 2k\mu \,.\, y, \quad y = \sin 2k\mu \,.\, x \pm \cos 2k\mu \,.\, y.$$

These two equations should be really the same, and they are so if we take the lower signs, in which case they amount to the following:

$$y = \tan k\mu \,.\, x, \quad \theta = k\mu, \text{ or } k\mu + \pi.$$

If the higher signs be examined, it will be found that the two equations are not identical except when $2k\mu = 2l\pi$, l being a whole number, which can be true only when n is a commensurable fraction. But this case being further examined, shows that no double points are indicated, but only that the curve itself is repeated *in all its points* after a proper number of revolutions of the deferent, as is otherwise sufficiently obvious. Consequently all the double points of a trochoidal curve lie in apocentral or pericentral radii, or in the radii opposite to them. Substitute for y and x their values in $y = \tan k\mu . x$, and this equation is easily reduced to

$$a \sin (\phi - k\mu) + b \sin (n\phi - k\mu) = 0;$$

from which the values of ϕ which belong to double points answering to different integer values of k are to be obtained by approximation.

The radius of curvature of any trochoidal curve is obtained from the formulæ (9, 10), and is as follows :—

$$\frac{\{a^2 + b^2n^2 + 2abn \cos (n - 1) \phi\}^{\frac{3}{2}}}{a^2 + b^2n^3 + ab\,(n^2 + n) \cos (n - 1) \phi}$$

It never becomes nothing except at the cusps of the epicycloid or hypocycloid; nor infinite except at the points of contrary flexure, or at the pericentre in the case of great approach to straightness already alluded to. The equation of the Evolute [INVOLUTE AND EVOLUTE], ξ and η being co-ordinates of a point in it, is involved in the following equations :—

$$\eta = a\,(1 - \kappa) \sin \phi + b\,(1 - n\kappa) \cos n\phi$$
$$\xi = a\,(1 - \kappa) \cos \phi + b\,(1 - n\kappa) \cos n\phi$$
$$\kappa \text{ being } \frac{a^2 + b^2n^2 + 2abn \cos (n - 1) \phi}{a^2 + b^2n^3 + ab\,(n^2 + n) \cos\ n - 1) \phi}$$

The evolute, then, of a trochoidal curve may be described as of an extended sort of planetary character, having an epicycle of variable size, and radius $b\,(1-n\kappa)$, which moves upon a deferent, also of variable size, whose radius is $a\,(1-\kappa)$. In one remarkable pair of cases this variation of the elements of the evolute ceases, namely, for the epicycloid and hypocycloid. If $b^2n^2 = a^2$, we find that κ becomes the constant $2 \div (1+n)$, and the equations of the evolute become those of a new epicycloid or hypocycloid, having its vertices at the cusps of the original involute.

The arc of the trochoidal curve cannot be obtained without the previous rectification of an ellipse, except in the case of an hypocycloid or epicycloid. In the former case the arc measured from the apocentre or cusp, formed while the deferential angle ϕ is produced, is

$$\frac{4ab}{a+b}\ (1 - \cos \frac{a+b}{2b}\ \phi\Big)$$

and the whole arc of descent is $4ab \div (a+b)$. The same for the epicycloid, the apocentre being now a vertex, is

$$\frac{4ab}{a-b} \sin \frac{a-b}{2b} \phi;$$

the whole arc of descent being $4ab \div (a-b)$. All the preceding formulæ may be reduced to those of the trochoidal form by the general equations before given.

The equations of the cycloid and simple trochoids may be, in an article like the present, best deduced from those of the double circular system. Remove the origin from the centre to the circumference of the deferent, we have then for the equations—

$$x = -a\,(1 - \cos \phi) + b \cos n\phi,\ y = a \sin \phi + b \sin n\phi.$$

Let a increase without limit, and let s be the arc of the deferent, described with a velocity α, while ν is the absolute angular velocity of the planet round the epicycle. We have then $s = a\phi$, and $\alpha : s :: \nu : n\phi$. Substitution gives

$$x = -a\,\Big(1 - \cos \frac{s}{a}\Big) + b \cos \frac{\nu}{\alpha} s, \quad y = a \sin \frac{s}{a} + b \sin \frac{\nu}{\alpha} s;$$

of which, when a is increased without limit, the ultimate equations are—

$$x = b \cos \frac{\nu}{\alpha} s, \quad y = s + b \sin \frac{\nu}{\alpha} s;$$

which are the equations of the common trochoidal system. Here an epicycle moves up the axis of y with a velocity α, while a planet revolves in the epicycle with the angular velocity ν. When νb is numerically greater than α, there is a curve with loops; when $\nu b = \alpha$, one with cusps; and when νb is less than α, one with undulations and contrary flexures.

To get the equations of the other extreme case, we must reduce the planetary form of the general equations to the trochoidal, which gives

$$x = (\mathrm{F} + \mathrm{R}) \cos \phi + \mathrm{C} \cos \left(\frac{\mathrm{F}+\mathrm{R}}{\mathrm{R}} \phi\right)$$
$$y = (\mathrm{F} + \mathrm{R}) \sin \phi + \mathrm{C} \sin \left(\frac{\mathrm{F}+\mathrm{R}}{\mathrm{R}} \phi\right)$$

Let $\mathrm{C} = \mathrm{H} - \mathrm{R}$: that is, let H be the distance of the planet from the circumference in contact of the rolling circle. Substitute for C, develop

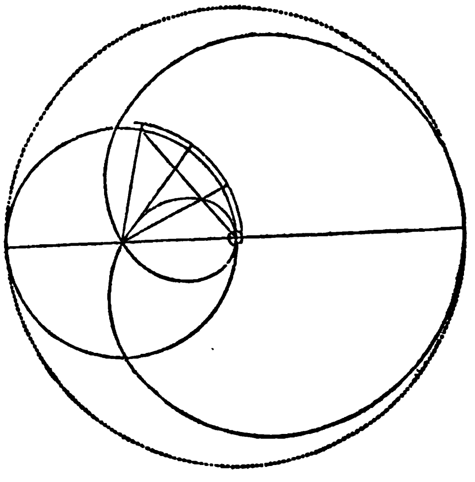
$$\mathrm{R} \cos \left(\phi + \frac{\mathrm{F}}{\mathrm{R}} \phi\right) \quad \text{and } \mathrm{R} \sin \left(\phi + \frac{\mathrm{F}}{\mathrm{R}} \phi\right)$$

into their binomial forms, and then increase the rolling circle without limit. The ultimate equations will be found to be

$$x = (\mathrm{F} + \mathrm{H}) \cos \phi + \mathrm{F}\phi \sin \phi$$
$$y = (\mathrm{F} + \mathrm{H}) \sin \phi - \mathrm{F}\phi \cos \phi$$

Here a tangent rolls over the fixed circle, carrying with it a point attached by a perpendicular arm of the length H. If $\mathrm{H} = 0$, we have the involute of the fixed circle; but if $\mathrm{H} = -\mathrm{F}$, in which case the moving point begins from the centre of the fixed circle, we can deduce $r = \mathrm{F}\phi$, $\theta = \phi - \frac{1}{2}\pi$, which gives the spiral of Archimedes. We have touched slightly on these extreme cases, but the mathematical student will find it a useful exercise to develop them more fully.

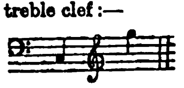
In conclusion, we wish to call attention to the fact that the specimens of curves in this article are all entirely the production of machinery. We are indebted for them to the kindness of Mr. Henry Perigal, a gentleman who practises the higher branches of turning as an amateur, and has devoted much time and money to the investigation of the effects of double and treble motions, as shown in various interesting publications. Most of those given in this article were executed in his lathe by means of Ibbetson's geometric chuck, a contrivance the results of which are well known to turners, but which have never been exhibited, as far as we know, in any article professing to give a mathematical classification of them.



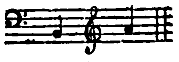
The preceding is the curve called the trisectrix in the article TRISECTION: it is a wood-cut made in the usual way from a drawing made in the lathe; all the rest are cut in the lathe.

TROMBONE (Italian, *great trumpet*). This ancient instrument was formerly known in England under the name of sacbut, from the old French *saquebute*. It is a deep-toned trumpet, composed of sliding tubes, by means of which every sound in the diatonic and chromatic scales, being within its compass, is obtained in perfect tune. The trombone is of three kinds,—the *alto*, the *tenor*, and the *base*, and these, in orchestral music, are generally used together, forming a complete harmony in themselves.

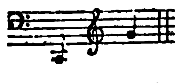
The scale of the *alto-trombone* is from C, the second space in the base, to G, an octave above the treble clef :—



The scale of the *tenor-trombone* is from B, the second line in the base to A, the second space in the treble :—



The scale of the *base-trombone* is from C, an octave below the second space in the base, to G, the second line in the treble :—



The trombone, when judiciously employed, as, for instance, in Mozart's 'Requiem,' and in his 'Don Giovanni,' is most efficacious in producing great and sublime effects; but, by the followers of the ultra-modern school, its power is exceedingly abused, especially in Italian operas.

TROPHY (*τρόπαιον, tropaeum*) contains the same root as the Greek verb *τρέπειν*, "to turn or to put to flight," and was therefore originally a sign or memorial erected on the spot where an enemy had been conquered or put to flight. The custom of erecting such memorials of victories, either on the field of battle or in the capital of the conquering nation, has been more or less common to all nations from the most remote to the most modern times. It was most general among the

Greeks, who used to erect trophies even after slight advantages; and it sometimes happened that both the belligerent parties, owing to some advantages they had gained, considered themselves entitled to erect trophies (Thucyd. i., 54; ii., 92). It was further a practice among the Greeks seldom to erect trophies in any other place than the field of battle, and that immediately after the victory was gained: when an enemy had been conquered at sea, the trophy was erected on the point of the coast nearest to the place where the victory was gained. A trophy in Greece after a victory on land appears to have consisted of a trunk of a tree fixed on some eminence and adorned with the spoils and armour of the vanquished. An inscription usually recorded the names of the conqueror and the conquered, and the whole trophy was dedicated to some divinity. It was customary not to make trophies of very durable materials, in order not to perpetuate the disgrace of a defeated enemy or to keep up any ill-feeling for too long a period. But this was not always observed. After a naval victory the trophy was usually adorned with the beaks of the captured ships of the enemy, and this custom was adopted by the Romans at an early period. The Romans down to the latter period of the republic never erected any trophies on the field of battle: the spoils of a vanquished enemy were partly distributed among the soldiers, partly dedicated in the temples of the gods, and partly applied as ornaments for other public buildings and places. When however the Romans adopted the custom of raising trophies on the field of battle, they usually consisted of more solid structures than the Greek, such as towers, columns, &c.

TROPICS (*τροπή, a turning*), the circles of the earth parallel to the equator which pass through those places to which the sun is vertical at the solstices, being the extreme boundaries of the torrid zone. The latitude of any spot upon either tropic is therefore the same as the obliquity of the ecliptic, and the interval between the northern and southern tropics comprehends every part of the earth at which the sun is ever vertical. The northern tropic is called the tropic of Cancer, and the southern that of Capricorn, since the sun, when vertical at places in the first, is at the commencement of the astronomical sign of Cancer; and when vertical at places in the second, is at the commencement of Capricornus.

TROUBADOURS, the name given to those poets in the Romance language, or Langue d'Oc, who lived in southern France, eastern Spain, and northern Italy, during the 12th and 13th centuries. [ROMANCE LANGUAGE.] The name is a French form, from the Provençal "trobador," a derivative of the verb "trobare," "to find," and means an "inventor." The word "Trouvère," in northern French, had the same meaning, and served to designate the poets of northern France, or of the Langue d'Oil. The troubadours were distinct from the jongleurs: the former were the real poets, and many of them were knights and men of noble birth, who occasionally occupied themselves with poetical composition; whilst the jongleurs were strolling minstrels, who did not compose poetry, but sang the lays of the troubabours, and accompanied them with their musical instruments, and thence derived their subsistence. Many of the troubadours however were skilled both in music and singing; but those who were not, retained a jongleur in their service. According to the spirit of chivalry, the nobles kept open house for all the wandering followers of war and minstrelsy, and often requited munificently both poets and musicians for their exertions to amuse them.

It was in the south of France that the poetry of the troubadours originated. That fertile region, blessed with a genial climate, had suffered less from the irruptions of the barbarians than the northern provinces of the kingdom, and had retained more of its old Roman civilisation: it hardly felt the civil wars of the Merovingian dynasty, and escaped the devastations of the Normans; and during the decline of the Carlovingians it became independent of the French crown by the revival of the kingdom of Bourgogne, or of Arles, and by the power of the great vassals, the counts of Toulouse and of Poitou and the dukes of Aquitaine. At the beginning of the 12th century the counts of Barcelona acquired by marriage the possession of Provence; and the whole region bordering on the Mediterranean on both sides of the Pyrenees, from the Ebro to the Var, became subject to one dynasty, whilst the people spoke the same, or nearly the same, Romance dialect. It was in the 12th century that the poetry of the troubadours attained its perfection: that poetry was essentially lyrical and mostly amorous, and was characterised by simplicity, or rather paucity, of ideas, and by a strained refinement of expression, and peculiarity of form, which made it quite distinct from the classical models. In that age and country of chivalry, every noble beauty had in her train some admiring poet; and every poet selected some fair lady—sometimes the daughter, but oftener the wife, of the nobleman to whose retinue he was attached—for the object of his poetical passion and the subject of his song. It was a poetical attachment, although it sometimes ended in a real one: its expression was artificial. These remarks apply generally to troubadour amatory poetry, to which however there are exceptions. (Sismondi, 'Littérature du Midi de l'Europe.')

The troubadours wrote also at times of loftier themes. Some of them, who had followed the Crusades and shared the dangers of Eastern campaigns, sang after their return the valiant deeds of the soldiers of the Cross. Others wrote to animate the Christian princes to deliver Palestine from the yoke of the Moslems. Others, especially about the time of the persecution of the Albigenses, wrote bitter satires against the persecutors, the Inquisitors, against the priesthood, the hierarchy, and against Rome itself. That persecution was one of the causes of the decay of troubadour poetry in the 13th century. Many of the troubadours perished, or fled and died in foreign lands. Afterwards Charles of Anjou, who had become count of Provence by marriage with the heiress of the house of Barcelona, having removed to Naples, took with him many Provençal knights and ladies to grace his new court. There they found a new language, the Sicilian or Italian, which was rising into maturity and was well calculated for poetry, and it became the favourite language of the Anjou court. When, in the following century, Queen Joanna I., being obliged to fly from Naples, returned to Provence, she endeavoured but in vain to revive the study of Provençal poetry; and when, many years later, she adopted Louis, son of King John, and the head of the third house of Anjou, that prince, who thus became possessed of Provence, spoke the Langue d'Oil, or northern French, and had no taste for the Provençal. His grandson René, duke of Anjou, count of Provence, and nominal king of Naples, made in the following century some attempts at reviving the poetry of the Langue d'Oc, but the race of the troubadours was now extinct, and the only result of his exertions was the collecting and compiling the lives of the old troubadours by the monks of the isles of Hyères, and after them by Hugues de St. Césaire.

At Toulouse however efforts were made to revive troubadour poetry. The "Capitouls," or municipal magistrates of that city, established an academy called "Del Gai Saber," or "of the gay science;" and seven of the best rhymers of the place, styled "the Seven Troubadours of Toulouse," were placed at the head of it. They fixed upon the 1st of May for holding an annual public festival, to which they gave the name of "Floral Games." The first meeting was held in 1324, and was attended by many poets from various parts of Languedoc. Maistre Arnaud Vidal de Châteauneuf d'Arri obtained the prize, and graduated as doctor of the gay science in consequence of a song in honour of the Virgin. The morality of troubadour poetry, however, underwent a reform under this new institution. It was forbidden by the statutes of the Academy to recite any composition on the subject of unlawful or adulterous love, a frequent theme of the old troubadours. The old language of the troubadours has long since fallen into disuse, and has given way to various patois, the Languedocian, Provençal, Poitevin, and others.

See for a thorough examination of troubadour poetry, with examples, Raynouard, 'Choix des Poesies Originales des Troubadours,' 6 vols. 8vo., Paris, 1816-21; 'Lexique Roman, avec un nouveau Choix des Poésies Originales des Troubadours,' Paris, 1836; also the work of Professor Diez, 'Die Poesie der Troubadours.'

TROUS DE LOUP, in the military art, are pits dug in the ground in the form of inverted cones or pyramids, in order to serve as obstacles to the advance of an enemy: each is made about six feet in diameter, or in breadth, and as many in depth, and a pointed stake is planted upright in the bottom. The pits should be disposed chequerwise in two or three rows, their centres being at distances of about ten feet from one another; and their sides should have such a slope that the enemy's riflemen, should they attempt to occupy them, may not be concealed in them from the view of the troops whom the pits protect.

The earth obtained from the excavations should be formed into a sort of glacis within the line of pits, in order that the enemy may not use it to fill them up. Trous de loup are generally formed before the salient points of field-works or in the intervals between them; and they are sometimes executed in rear of such works in order to protect the gorges when these are without parapets.

TROVER (from the French word *trouver*, "to find"), the name of an action invented for the purpose of ascertaining the right, as between the plaintiff and defendant, to the personal chattels which are the subject of it. This action is maintainable by one who has either an absolute or special property in the chattels and also a right to possession. Thus it may be brought either by the actual owner or an occasional bailee, a carrier, &c., or a mere finder as against all except the rightful owner. The declaration formerly stated that the plaintiff was lawfully possessed as of his own property of certain personal chattels, naming them distinctly, their amount and value; that he afterwards casually lost them, and that they came into the possession of the defendant by *finding*, who, afterwards converted them to his own use; for which the plaintiff claimed damages. This form and the fiction respecting the loss and finding of the goods were contrived for the purpose, by assuming a right of possession in the defendant, of enabling the parties to try the bare question of *right*. These fictions are not now used; and the fact of *conversion*, which is the gist of the action, is proved by showing that the defendant upon request refused to deliver up the goods, or has destroyed them, or has assumed the right to dispose of them. When an act of conversion has once been completed, no subsequent act by the defendant can, as is said, "purge the conversion;" that is, the right of action, having once vested in the plaintiff by the act of conversion, will not be divested by any subsequent act of the defendant. But such a subsequent act, as for instance the return of the goods, may reduce the damages to a merely nominal character. The action is not maintainable by one joint tenant, or tenant in common, or partner against another, unless in the case where the chattel has been destroyed by the other. This rule is founded on the principle that the possession of one is, by reason of the joint property of all, held to be the possession of all, and therefore no act of conversion can be said to have been committed.

The answers to this action are, a denial of the property of the plaintiff in the chattel; or the statute of limitations, namely, that six years have elapsed since the act of conversion was committed; or any circumstances showing that the defendant has a right to detain the goods, as from having a lien upon them, &c.

The plaintiff must prove that the nature and value of the goods are as stated in the declaration. If he succeed in obtaining a verdict, the jury may give damages to the amount of the value of the goods, and also such sum in addition as may cover the amount of interest during the time subsequent to the conversion. This action differs from the action of detinue as being brought to recover damages, while the object of the action of detinue is to recover the actual goods in specie. [DETINUE.]

TROY WEIGHT. Neither the etymology nor the time of introduction of this denomination is well known. The received opinion is that it took its name from a weight used at the fair of Troyes: this is likely enough, since we find more than one large town the weights of which became standards: thus we have the pound of Cologne, of Toulouse, and perhaps also of Troyes.

That there was a very old English standard pound of twelve ounces is a well determined fact; and also that this pound existed long before the name Troy was given to it, another. There were also the merchants' pound of fifteen ounces, and the Tower pound, having twelve ounces of its own, but less than the Troy pound by three-quarters of an ounce. Though the troy pound was mentioned as a known weight in 2 Henry V., cap. 4 (1414), and 2 Henry VI., cap. 13 (1423), the term troy was not applied to the legal standard pound till 12 Henry VII. (1495). The merchants' pound seems to have been the origin of AVOIRDUPOIS weight.

The troy pound has continued to be the legal standard down to the present time, though only actually used in weighing precious metals and stones, and apothecaries' drugs. It had precisely the same limitation of use in the time of Fleta, who is supposed to have lived in the reign of Edward I. There is no doubt that it was originally the pound of silver, the pound sterling, and there is evidence that this pound was sometimes described as divided into twenty parts called shillings. The famous statute of Henry I. (1266) makes a standard for it from the weight of ears of wheat.

The pound troy is now divided, for gold and silver, into twelve ounces, each ounce into twenty pennyweights, and each pennyweight into twenty-four grains. But for medicines, it is divided into twelve ounces, each ounce into eight drams or drachms, each drachm into three scruples, and each scruple into twenty grains. A cubic foot of water weighs 75·7374 pounds troy. [WEIGHTS AND MEASURES.]

TRUCK SYSTEM. TRUCK ACT. Truck, which means exchange or barter, has come to be appropriated to signify the payment of wages of labour in goods, and not in money. By the truck system is meant this mode of paying wages, together with the mass of its tendencies and results. The Truck Act, 1 & 2 Wm. IV., cc. 36, 37, is an act passed in 1831, which, repealing all the previous acts passed for the same purpose, provided anew and more stringently for the prevention of payment of wages in truck in the departments of industry therein enumerated. The wages of agricultural labourers and domestic servants are exempted from the operation of the act.

It is to be observed, in the outset, that the chief part of the evil of what is called the truck system is incidental, and not essential to the payment of wages in truck, and arises out of the power of the master over the workman, which enables the former to use this mode of paying wages to defraud and oppress the latter. A master may pay the wages of his workmen wholly or in part in truck, in articles of food, clothing, &c., either by agreement or with the understood consent of his workmen; and if he supply these articles at prices no higher than those at which they are to be procured elsewhere, and study to meet the various wants of the workmen and their families, the utmost harm that can result is the loss to the workmen of the moral and economical lessons which the disbursement by themselves of weekly money-wages is fitted to supply, and the interference with the business and profits of neighbouring retail shopkeepers; and there will always in such cases be some advantage to set against these, so far as they go, evil results. Where the truck system acts beneficially, it is owing entirely to the justice and benevolence of the individual truck-masters. On the character of the master everything depends. In the hands of masters of opposite character, and under circumstances, whether of scarcity of employment, of isolated situation, or of combination among masters in the same business, or through an extensive district, which place the workman more or less at the mercy of his employer, the payment of wages in truck may be, and continually has been, and is still, extensively used for the defrauding and oppressing of workmen.

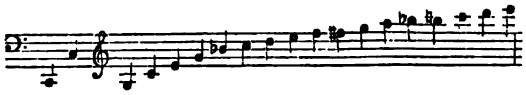
The following is a summary of the Truck Act, often known as Mr. Littleton's Act, which was passed in 1831. It declares all contracts for hiring of the artificers afterwards enumerated, by which wages are made payable wholly or in part otherwise than in the current coin of the realm, or which contain regulations as to the expenditure of wages, to be illegal, null, and void. All payment of wages is to be in money entire; and any payment of wages in goods is declared illegal. Wages which have been paid otherwise than in the current coin of the realm are made recoverable; and in an action brought for the recovery of wages, no set-off is to be allowed for goods given in payment of wages, or for goods sold at any shop in which the employer has an interest. Employers are denied an action in return against artificers for goods which have been supplied in payment of wages. If workmen or their wives or children become chargeable to the parish, overseers may recover from their employers wages which have been earned within three months previous, and have not been paid in money. The penalty on employers making the illegal contracts or illegal payments of wages to be, for the first offence, a sum not greater than 10*l.* not less than 5*l.*; for the second, a sum not greater that 20*l.* nor less than 10*l.*; and the third offence is declared a misdemeanor, and the employer who has been convicted to be punishable by fine within the discretion of the convicting magistrates, but not in a sum greater than 100*l.* The convicting justices are empowered to award a portion of the penalty, which shall never exceed 20*l.*, to the informer. The penalties may be sued for and recovered by any one before two justices of the peace having jurisdiction in the county, riding, city, or place within which the offence has been committed. No justice of the peace being engaged in any of the trades or manufactures enumerated in the act, or the father, son, or brother of such person, shall act as a justice of the peace under this act; and provision is made for county magistrates taking the place of borough magistrates thus disqualified. Justices are empowered to compel attendance of witnesses. Power is given to levy the penalties by distress. A member of a partnership is not liable personally for the offence of his partner, but distress may be made on the partnership property. The 19th clause thus enumerates the artificers to whom the act relates:—"Artificers employed in or about the making, casting, converting, or manufacturing of iron or steel, or any parts, branches, or processes thereof; or in or about the working or getting of stone, salt, or clay; or in or about the making or preparing of salt, bricks, tiles, or quarries; or in or about the making or manufacturing of any kinds of nails, chains, rivets, anvils, vices, spades, shovels, screws, keys, locks, bolts, hinges, or any other articles or hardwares made of iron or steel, or of iron and steel combined, or of any plated articles of cutlery, or of any goods or wares made of brass, tin, lead, pewter, or other metal; or of any japanned goods or wares whatsoever; or in or about the making, spinning, throwing, twisting, doubling, winding, weaving, combing, knitting, bleaching, dyeing, printing, or otherwise preparing of any woollen, worsted, yarn, stuff, jersey, linen, fustian, cloth, serge, cotton, leather, fur, hemp, flax, mohair, or silk manufactures; or in or about any manufactures whatsoever made of the said last-mentioned materials, whether the same be or be not mixed one with another, or in or about the making or otherwise preparing, ornamenting, or finishing of any glass, porcelain, china, or earthenware whatsoever; or any parts, branches, or processes thereof; or any materials used in any of such last-mentioned trades or employments; or in or about the making or preparing of bone, thread, silk, or cotton lace, or of lace made of any mixed materials." Domestic servants and servants in husbandry are exempted from the act. The 23rd clause declares that nothing in the act shall prevent the supplying to artificers of medicine or medical attendance; or fuel, materials, tools, or implements to be used in his trade or occupation, if a miner; or of hay, corn, or other provender to be consumed by any horse or beast of burden, or the letting to any artificer the whole or part of any tenement, or the supplying of victuals dressed under the roof of any employer and there consumed; and making deduction of wages on any of the above accounts, or on account of money advanced, "provided always that such stoppage or deduction shall not exceed the real and true value of such fuel, materials, tools, implements, hay, corn, and provender, and shall not be in any case made from the wages of such artificer unless the agreement or contract for such stoppage or deduction shall be in writing and signed by such artificer." The interpretation clause (25th) gives a most extensive meaning to the word contract: "Any agreement, understanding, device, contrivance, conclusion, or arrangement whatsoever on the subject of wages, whether written or oral, whether direct or indirect, to which the employer and artificer are parties or are assenting, or by which they are mutually bound to each other, or whereby either of them shall have endeavoured to impose an obligation on the other."

Such are the provisions of the Truck Act. Well adapted, as it would appear, for the purpose of protecting the workman against this species of oppression by his master, it is yet extensively violated and evaded.

TRUE. (Astronomy.) This word is used in a somewhat technical sense. The place which a star or planet appears to occupy in the heavens is not called its true place, but that which it would occupy if the effects of refraction, parallax, &c., were removed, that is, if the spectator saw from the centre of the earth, and without the light passing through any refracting medium.

TRUMPET, a musical instrument of the highest antiquity, which, under different names and forms, has been known in all ages that have left any records, and in all countries, however remote from civilisation. Ménage derives the word from *στρόμβος*, *turbo*, a shell, and this etymology indicates the origin of the instrument, which still appears in what probably was its pristine shape among many barbarous tribes in different parts of the globe. [BUCCINA.]

The trumpet is a single tube eight feet long, less in diameter than the horn, doubled up in a parabolic form, sounded by means of a mouth-piece, and subject to the same acoustical laws which govern all instruments of this class. [Horn.] The natural scale of the trumpet, as given by Karl Bargans, is as follows:—



"By the assistance of a small brass tube, called the tuning-pipe, or shank, by which the tube of the trumpet is lengthened, the above number of notes may be increased." [Harmonics.]

Music for the trumpet, as in the instance of the horn, is always written in the natural key of C, and the key to which the instrument is to be adapted is pointed out by the composer.

TRUNCATED, cut off, or abridged. Thus the part of a cone or pyramid which remains when the vertex and parts adjacent are separated from the rest by a plane section, is called a truncated cone or pyramid.

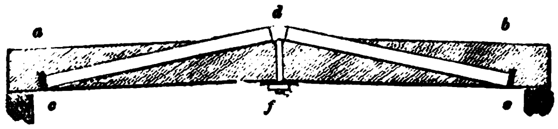
TRUNNIONS. When a heavy body has to be supported so as to be freely moveable in a vertical plane, it is furnished with a couple of strong cylindrical pins, or *trunnions*, projecting from its sides, and resting in semi-cylindrical grooves placed at equal heights in the supporting pillars, so that a line connecting the trunnions is horizontal. In this way the body may be placed in any position in a vertical plane at right angles to such line.

TRUSS. [Hernia.]

TRUSSING. The principle of trussing, as applied to the timber framework of roofs, is explained under Roof. It remains to notice some of the methods in which that principle is applied to the support or strengthening of beams or girders, which may, by their judicious application, be made available for much larger spans, and for the support of much greater weights, than simple beams of any attainable dimensions.

The rods or bars which are added to a girder for the purpose of trussing or supporting it may be applied in two sets, one on each side of the girder, and connected together by short cross-pieces at the necessary points; or the beam or girder itself may be divided longitudinally into two halves, or *flitches*, separated just so far as to admit a single truss between them, and held in the right position by the insertion of small blocks. In trussed girders formed in the latter way it is well to reverse the position of one of the flitches, so that the weaker end of one may lie alongside the stronger end of the other. One of the simplest methods of trussing girders is that represented in *fig.* 1, in which *a b* is the beam, resting upon walls or other fixed points of support at its extremities, and *c d* and *d e* are two inclined struts, resembling the rafters of a roof. These abut, at their lower extremities, *c* and *e*, upon iron plates inserted in the timber; and they sustain the centre of the beam by means of a *king-bolt*, *d f*, suspended from their apex, and passing through an iron plate which bears against the under side of the beam. This bolt corresponds with the king-post in the truss of a roof, and the lower part of the beam, between *c* and *e*, acts the part of a tie-beam.

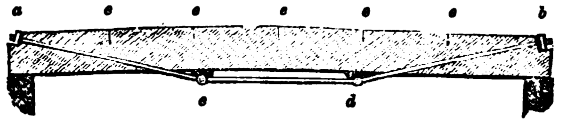
Fig.1.



By screwing up the nut *f*, on the lower end of the king-bolt, the beam is *cambered*, or slightly curved upwards, as shown in the cut, and so long as it retains this curvature the weight laid upon it must eventually press upon the trussing-bars, being transmitted to them through the king-bolt. The defects of this mode of trussing consist in the circumstance that the beam will not, so long as it retains the cambered form, sustain any part of the load, but will of itself throw considerable strain on the truss; and that the lower edge of the beam, although required to be in a state of tension, to act as a tie connecting the abutments *c* and *e*, is really in a state of compression, because it forms the inner part of the curve, which is necessarily shorter than the outer line formed by the convex top of the beam. "Notwithstanding these obvious defects," observes Mr. Ainger in a communication to the Society of Arts ('Transactions,' vol. xlviii. p. 101), "this mode of trussing continued to be much employed till about the year 1816, when Mr. Barlow, among other valuable experiments, compared girders trussed on the principle above described with a plain piece of timber of the same size, and found the latter to be on the average not considerably weaker." These defects are remedied by connecting the lower ends of the inclined bars, which are, though not very properly, called braces, by an iron rod stretching in a perfectly straight line from *c* to *e*, and capable of being brought to any required degree of tension by means of screws or keys. This addition makes the truss perfect in principle, its strength being limited only by that of the materials employed, which may be either iron alone, or iron and wood. In some cases the inclined bars are not continued upwards until they meet in an apex, and a third bar, in a horizontal position, is placed between their upper ends. This horizontal piece resembles the straining-sill of a truncated roof, and the vertical bolts, of which two are used, take the place of queen-posts.

In the paper by Mr. Ainger above referred to, it is observed that trusses on the above principle are difficult and somewhat expensive to make in an effectual manner; and a more economical plan is described, which, though not equally efficient, adds very greatly to the strength of the timber. The description is illustrated by a representation, of which *fig.* 2 is a copy, of a girder thirty-four feet long, used to support a leaden flat, and which had been found to stand without sensible alteration for two years. The beam *a b* is cambered in a similar degree to that shown in *fig.* 1, and the trussing consists of a series of iron rods, *a c*, *c d*, and *d b*, pulling against iron plates or abutments notched into the timber at *a* and *b*, and connected together at the joints *c* and *d*, by bolts similar to those used in the chains of a suspension-bridge, the rods *c d* being double, and embracing the ends of *a c* and *d b* between them. The truss forms, in fact, a suspension-bridge, supporting the middle of the beam at *c* and *d* by means of small blocks inserted between it and the connecting-bolts. The ends of the truss, *a* and *b*, are prevented from approaching each other by the upper part of the beam, which should therefore be in a state of compression; and in order that it may be so, notwithstanding the extension of the fibres by the cambering of the beam, notches may be cut about one-third through the substance of the wood, as at *e*, *e*, *e*, *e*, *e*, which, after the curving of the beam, are filled in with wedges of hard wood or iron. The upper edge of the beam is thus enabled effectually to resist the tension of the rods, the strength of which forms the only limit to that of the girder. Several varieties of this plan of suspension-trussing are given in Hebert's 'Engineer's and Mechanic's Encyclopædia,' vol. i., pp. 158-161. It may be applied, like the former system, either to single girders or to those consisting of two flitches. Ainger gives a formula for calculating the size of the iron trussing-rods, which, for a beam thirty-four feet long, should have a cross-section of rather more than a square inch for every ton weight to be sustained in the centre of the beam. It was found by experiment that a fir beam eight inches square and twelve feet long between the supports, strengthened by iron rods one inch square, applied as in *fig.* 2, would support between 4000 and 5000 pounds, which is more than double the weight it would sustain without trussing. A girder of the same dimensions, trussed with iron braces on the principle of *fig.* 1, but with the addition of a horizontal tie-bar one inch square, appeared to possess no greater strength to resist fracture, although its deflection under similar loads was less, owing to the iron braces being less compressible than the fir-wood, which, on the suspension principle, has to resist the tension of the rods.

Fig. 2.



The late Mr. George Smart, inventor of the ingenious truss called the "bow-and-string-rafter," in experiments tried to ascertain how far the strength of a beam is increased by confining its ends, so as to prevent them from approaching each other when the centre is heavily loaded, found that a lath which, when simply laid on two points of support, broke with a load of 11 lbs. placed in the middle, would sustain 270 lbs. when the ends were firmly secured by wedges. These experiments led him to the construction of trussed beams of unusual lightness, in wrought-iron as well as in wood. In 1826 he submitted to the Society of Arts a wrought-iron beam adapted for use in bridges, roofs, floors, and other constructions in which stiffness, strength, and lightness are required, for the invention of which he was rewarded with their silver Vulcan medal. This beam or girder is made by welding the ends of an arched bar of wrought-iron to a longer straight bar, and then turning the ends of the straight bar either up or down, as may be most convenient for fixing, according to the particular use to which it is to be applied. Blocks of well-seasoned wood are then inserted at intervals between the arch and the straight bar, to prevent buckling, and the whole is held together by iron straps inclosing the blocks and the iron bars. Mr. Smart conceived that wrought-iron beams made in this way would support so much more weight than those of cast-iron of similar dimensions, that they might be made of any given strength for one-half the cost of cast-iron girders; and he refers to the application of such a beam to sustain a very heavy mass of brickwork over a gateway leading from the Poultry, under circumstances which would have precluded the use of timber. Very light timber beams were made by Mr. Smart upon the same principle; and so strong was his confidence in the application of trussing upon an extensive scale, that he published a design for a foot-bridge of trussed timber to cross the river Thames at Hungerford by a single span.

Cast-iron beams are frequently trussed with wrought-iron rods, in a similar manner to those of wood, and are applied to purposes for which great strength is required. The brest-summers used over large shop-windows, to sustain the front wall of the house, are often made in this way; and similar girders are much used in the construction of railway bridges. The bridge which supports the London and Blackwall Railway across the street called the Minories is a remarkable example. It has a clear span of sixty-three feet, and is supported by six massive trussed beams, weighing about fifteen tons each. When used in floors or roofing, timber may be applied on each side of the iron, supported by ledges formed for the purpose, to render the fitting of the joists and other timbers easy. Smart recommends the use of bridging and ceiling joists formed of wide hoop-iron riveted together, with a slip of poplar between them to hold the flooring or lath-nails; and he observed that neither fir nor oak will, when thin, receive nails near so well as poplar, without splitting: in addition to which he says that, besides being very durable if kept dry, it has the advantage of being much less combustible.

Trussing has been applied with advantage to the raising of sunken floors, and the repair of beams which, from sagging or from the ravages of dry-rot, have become dangerous. In the forty-second volume of the 'Transactions of the Society of Arts,' pp. 149-152, is an account of a method of raising a sunken floor, which had been successfully practised by Mr. F. Richman, and for which he was rewarded with the large silver medal of the Society. The floor on which he had operated had sunk in the middle to the extent of five inches, and had become very tremulous, in consequence of the removal of a trussed partition, in order to throw two rooms into one. The ceiling and cornice of the room below being valuable, it was desirable to apply a remedy from above, which was accomplished by removing the floor, and applying to each side of the sagged beam a cast-iron arch, of which the span was equal to the length, and the height or spring equal to the depth, of the beam. The ends or abutments of these arches were united by tie-rods of wrought-iron. Four equidistant holes were then cut transversely through the beam near its lower edge, and in each of these was placed a short bar, having an eye projecting on each side of the beam. Through these eyes were passed vertical bars or trussing-bolts, which rose above the top of the beam, and were there connected together by cross-pieces, which rested upon blocks attached to the cast-iron arches. By screwing down nuts upon the upper ends of these bolts, as the arches themselves could not yield, the beam was compelled to rise, and was so restored to its original straightness. The cast-iron arches and their tie-rods were formed of several small pieces, so that they might be very conveniently applied; but for the method of accomplishing this, and for other matters of detail, we must refer to Mr. Richman's account, which is illustrated with engravings. In the same volume (pp. 153-164) is an account of the means adopted by Mr. Alfred Ainger for supporting the decayed timbers of the roof of the church of St. Mary Aldermary, in the city of London, by means of cast-iron trusses or cradles. This operation was performed under circumstances of unusual difficulty, some of the beams being so much decayed by the dry-rot as to have lost all bearing upon the walls. The ingenious contrivances adopted, which were rewarded by the Society of Arts with their large gold medal, prevented the necessity for destroying a richly-ornamented ceiling, the restoration of which would probably have cost 5000*l.*

TRUST AND TRUSTEE. A trust, which is in fact only a new name given to a use, is well defined by Lord Coke in the words employed by him for the definition of the latter term, namely: "A confidence reposed in some other, not issuing out of the land, but as a thing collateral, annexed in privity to the estate of the land, and to the person touching the land, for which *cestui que use* has no remedy but by *subpœna* in Chancery." (Co. Litt. 272 b.) The explanation of the terms of the above definition, and an account of the origin of uses and trusts, and their connection with each other, will be found under Uses. The purpose of this article is to give a general account of the nature, constitution, and objects of trusts, of the duties and liabilities of trustees, and of the rights and estate of the *cestui que trusts*, that is, of the persons beneficially entitled under trusts.

The first division of trusts is into simple and special. The simple trust corresponds exactly with the ancient use, and is where property is simply vested in one person for the benefit of another, the terms of the trust not being specified, but left to the construction of law. The special trust, on the other hand, is where property is vested in a trustee for purposes particularly pointed out, and where therefore he is not the simple depositary of the estate, but is bound, in his character of trustee, to the active performance of certain duties. Special trusts are further subdivided into ministerial and discretionary; the former being such as require for their performance only the ordinary qualities of a rational agent, the latter such as involve the exercise of more or less judgment and discretion.

I. Of the creation of trusts.

1. And first, as to trusts created by the act of a party.

A declaration of a trust is regarded in equity as a gift or conveyance of property to the persons who are the objects of the trust, and therefore the capacity to declare a trust is limited by the same rules as the power of disposing of property at law. Thus persons under the disabilities of coverture, infancy, lunacy, or idiotcy are incapable of creating trusts wherever they would be incapable of conveying at law.

By the common law, trusts might be created by parole, but by the seventh section of the Statute of Frauds (29 Car. II. c. 3) it was enacted that "all declarations, or creations of trusts or confidences in any lands, tenements, or hereditaments, shall be manifested and proved by some writing, signed by the party who is by law enabled to declare such trust, or by his last will in writing, or else they shall be utterly void and of none effect." The words "lands, tenements, and hereditaments" in this clause can have no application to personal estate, trusts relating to which are therefore not affected by the statute; but they comprise chattels real (3 Ves. 696) and copyholds (Amb. 151.) It is to be observed that the statute does not require trusts to be *declared* in writing, but only to be *manifested and proved* by writing; and therefore, though the language of the 9th section as to grants and assignments of trusts renders it probable that the intention of the act was that the declaration itself should be in writing, it is established that the statute is satisfied if the trust be manifested by any subsequent acknowledgment on the part of the trustee, however informal or indirect, as by a letter under his hand, his answer in Chancery, or by a recital in a deed, &c.; and though the writing itself must be signed, the terms of the trust may be collected from a paper not signed, provided it can be clearly connected with the signed writing. (3 Ves. 696; 2 Vern. 288; 2 P. W. 412.)

The enactments of the Statute of Frauds with respect to wills, as now modified by 1 Vict. c. 29, also indirectly affect the creation of trusts. As wills must be executed according to certain formalities, it follows that a trust of realty or personalty cannot be created by will without the observance of the proper solemnities; and it has been determined that, if the legal estate be effectually devised, but the declaration of trust be not duly attested, the devisee of the legal estate will be entitled to the beneficial interest (3 Atk. 141); though if there be *mala fides* on the part of the devisee or legatee, as if there be an express or implied undertaking to execute the intent, a court of equity will establish the trust notwithstanding the statute. (2 Vern. 559.)

A trust may be created either directly, by express declaration, or indirectly, without mention of a trust in words, by the expression of an intention, which the court of equity will execute as a trust.

In direct declarations of trust, technical words are not necessary; but it is established as a general rule that, where they are employed, they are to be taken in their legal and technical sense. A distinction however is made in this respect between what are called trusts executed, in which the limitations are complete and final, and trusts executory, in which the expressed limitations are not intended as complete in themselves, but only as directions or instructions for a settlement to be afterwards executed. To the former the rule is strictly applicable, while with respect to the latter a court of equity will endeavour to execute what appears to be the intention of the parties, notwithstanding the use of inappropriate technical words; and the only difference in this respect between executory trusts in marriage articles and in wills is, that the known objects and purposes of the former afford a clue to the intention, which in the latter can in general be collected only from the language of the instrument. (Fearne, 'Cont. Rem.' 94, 114.)

When the owner, or the person otherwise entitled to the disposition of property, shows an intention to exercise it in favour of another, the court, unless where there is a want of consideration, will execute that intention, however informally expressed. Thus when a person has contracted with another for the sale of his estate, he becomes thereby a trustee of the estate for the purchaser; or if a testator, without expressly devising his lands, direct them to be sold for payment of debts and legacies, the lands will descend to the heir as a trustee for the creditors and legatees.

Trustees being considered merely as the instruments through which a trust is to be carried into execution, the Court of Chancery will not allow a trust to fall to the ground from the want of trustees, or their refusal to act, but will appoint proper persons to administer the trust.

In general all persons capable of acquiring the legal estate in property are capable of being trustees, and are bound by the trusts declared of it; though an exception should perhaps be made with respect to property vested in the king, against whom there is no remedy in Chancery, though the subject might sue the crown by preferring a petition of right. (Hardres, 467; 1 Ves. 446.) The fitness of a person for the office of trustee however depends on his capacity to discharge the discretionary part of the trust, and to join in the requisite assurances relating to the property: *femes covert* and infants, on account of the disabilities they labour under, are not proper persons to select for the office of trustees. An alien may discharge the office of trustee of personal chattels, though not of lands or chattels real, as he could not sue or be sued respecting such property; besides which, the legal estate of the property so conveyed to the alien would vest, on inquisition found, in the king. (Gilb. 'On Uses,' 43; 2 Mer. 431.)

2. As to trusts created by operation of law.

Trusts of this kind may arise in three ways: 1st. Where the trust originally derives its existence from operation of law; 2ndly. Where a trust already in existence is revived by operation of law, as against a particular property; and, 3rdly. Where a trust already in existence, and annexed to a particular subject-matter, arises *de novo* by operation of law as against a particular person.

Trusts of the first kind arise either where an estate is purchased in the name of one person, and the consideration is paid by another, in which case a trust of the legal estate arises for the person who advances the purchase-money; or where, upon a conveyance or will, the grantee, devisee, or legatee is intended to take the mere legal estate, and the beneficial interest is left wholly or partially undisposed of: in which case a trust of so much of the beneficial interest as is undisposed of results to the settlor or his heir, if the subject be real estate, and if it be personal estate, to himself or his personal representative. The intention to exclude the person to whom the legal estate is given from the beneficial interest may either be presumed from the circumstances or actually expressed upon the instrument. Whenever, upon a conveyance or will, a trust is declared of part of the estate, and no mention is made of the residue, the partial declaration is considered to have been the sole object of the settlor, and the remaining interest results to him or his representative. But if no trust be expressed of any part of the estate, the grantee or devisee must, in the absence of *mala fides* on his part, be considered as beneficially entitled to the whole. (2 Bro. C. C. 589; 1 Atk. 448.)

A trust of the second kind arises when the estate is converted by the trustee from one species of property to another, either in pursuance or in breach of his duty. If the property in its original form was subject to a trust, the *cestui que trust's* interests cannot be affected by any change in that form. Thus where trust-money has been laid out in the purchase of land, and where the rents and profits of land have been laid out in the purchase of stock, the land and stock have been held bound by the same equity to which the money laid out in the purchase was subject. (8 Ves. 46; 1 Atk. 49.) In the same manner, if a trustee or other person invested with a fiduciary character obtain a renewal of a lease in his own name and at his own expense, the trust which was annexed to the original term will attach upon the renewed lease, and the trustee will be entitled only to the amount of expense incurred. (11 Ves. 391; 1 Eden, 453.)

The third kind of trust by operation of law arises wherever the property passes from the trustee into the hands of a person who takes by a derivative title. The heir, devisee, or personal representative of a deceased trustee takes the property in the same character, and is bound by the same equity. Where the trust estate has passed to a stranger by conveyance, if he be a volunteer,—that is to say, if there was no proper consideration for the conveyance,—he will be bound by the trust, whether he had notice of it or not. (2 P. W. 678.) If, however, the grantee was the purchaser of the estate for an adequate consideration, then, if he took with notice of the trust, he will be bound by it, in the same manner as the person from whom he purchased; but a *bonâ fide* purchaser, without notice of the trust, is not affected by it; and his title, even in equity, cannot be impeached. (15 Ves. 350; 2 B. & B. 318.)

II. Of the estate and office of trustees.

1. Of their estate.

Whenever a trust is created, it is a general rule that a legal estate, sufficient for the purposes of the trust, shall, if possible, be implied; and also that the legal estate limited to trustees shall not be construed to extend beyond what the purposes of the trust require. Thus the court has in many cases extended the estate, so as to make it commensurate with the objects to be effected, and even supplied the estate when it was altogether wanting. (1 Ves. 495.) On the other hand, the court has frequently restricted the estate which trustees would have taken by the wording of the instrument. (7 T. R. 433.) But these rules, so far as they relate to devises, must now be considered with reference to the 1 Vict. c. 26, by the 30th section of which it is declared that where any real estate, other than a presentation to a church, is devised to a trustee or executor, such devisee shall be construed to pass the whole estate which the testator had power to dispose of in the property, unless a definite term of years, absolute or determinable, or an estate of freehold, be thereby given to him expressly or by implication.

The legal estate vested in a trustee has in general the same properties and incidents as if the trustee were the beneficial owner. Thus it is liable to curtesy, dower, and free-bench, and at the common law it was subject to forfeiture to the king and escheat to the lord; but the law is now altered, and the devolution of such estates is not affected by the attainder or conviction of the trustee or mortgagee. The legal estate in the property, whether real or personal, may be conveyed or assigned by the trustee, who may likewise devise or bequeath it by his will, though trust-estates will not always pass in a will by the same words as other property, and the question in each case is one of presumed intention. (8 Ves. 417.)

2. Of the general properties of the office of trustees.

Acceptance of the office by a trustee may either be by express declaration or be implied from his proceeding to perform the duties of it. No general rule can be laid down as to what particular acts will constitute an acceptance of the office by a trustee, which is a question to be determined by the circumstances of the particular case: it may, however, be stated generally that every voluntary interference with the trust-estate will be construed as an acceptance of the trust; and that where a trustee acts ambiguously he will not be allowed afterwards to take advantage of the doubt, and deny that he acted in the character of trustee. (2 Ves. Jun. 678; 1 Ves. 552.)

But as no one is compellable to undertake a trust, it is in the power of the person appointed a trustee to renounce the office by what is called a disclaimer, which, if he intend to decline the office, he ought to execute without delay. A disclaimer ought to be made by deed, and should purport to be a disclaimer, and not a conveyance, which, as it transmits the estate, would, strictly speaking, imply a previous acceptance of the trust, though instruments of this kind receive a liberal construction. (2 Swanst. 372; 2 M. & K. 278.)

The general properties and qualities of the trustee's office may be stated under the following heads:—

(1.) A trustee having once accepted his office cannot afterwards renounce it. The only modes by which he can be released are a decree of a court of equity, a power reserved on the instrument creating the trust, or the consent of all the persons beneficially interested in the estate. (2 Sch. and Lef. 245.)

(2.) The office of trustee, which implies personal confidence, cannot be delegated (2 Ves. 640), though a trustee may sometimes perform a mere ministerial duty through an attorney or proxy. (1 Ves. 413.)

(3.) When there are several trustees, the administration of the estate is vested in all; and therefore if one refuse to act, the others cannot proceed without his concurrence, and the Court of Chancery must take upon itself the administration of the trust. (2 'Eq. Ca. Ab.' 742.)

(4.) Where one of several trustees dies, the joint office may be exercised by the survivors. This is a consequence of the general maxim of law, that though a bare authority given to several determines by the death of one, if the authority be coupled with an interest it survives. (Co. Litt. 113 a, 181 b.)

(5.) One trustee is not liable for the acts of his co-trustee in which he has not joined, and this is equally true whether there is a proviso to that effect in the settlement or not. (Bridg. 35; 18 Ves. 254.) And even if a trustee joins in a receipt for money required for the purposes of the trust, for the sake of conformity only, he will not thereby become responsible for the application of it, though it will be upon him to prove that his co-trustee was the person by whom the money was received. (11 Ves. 324; 1 Ed. 147.) The rule is different with respect to co-executors, each of whom has an absolute control over the property, and who are therefore under no obligation to join in giving receipts (Amb. 219; 3 Swanst. 64); though whenever their joining together in doing any act is necessary, the same rule applies to them as to other trustees. (7 Ves. 197.) But if a trustee allows money to remain improperly in the hands of his co-trustee, or is cognisant of a breach of trust committed by him, and takes no measures to protect the estate, he will become himself responsible. (11 Ves. 319.)

(6.) Trustees cannot derive any private advantage from the administration of the trust, and therefore all profits made by the trustee in the management of the trust estate, in whatever manner, belong not to him, but to the *cestui que trust.* (2 M. & K. 664.)

III. Of the duties of trustees.

Trustees of personal estate are bound to use all due diligence in getting in and reducing into possession all parts of the trust estate that may happen to be outstanding at the time of the commencement of the trust (1 Mad. 290), and in providing for the safe custody of the property. (1 Ed. 148.) They are also bound, where trust-money cannot be applied immediately, to invest it on proper security, so as to render it productive to the *cestui que trust.* In the absence of any specific direction as to investment in the trust-deed, the rule is that the trustees ought to invest in the public funds.

Where a trust-estate consists of renewable leaseholds, it is in general the duty of the trustees to provide for renewals. If there be an express trust to provide for the fines out of the rents and profits, the trustees should lay aside a proper proportion of the annual income for the purpose. (17 Ves. 485.) If there be no express direction for payment of the fines, the estate may be charged with the amount of the fine, and the rule of the court is that the tenant for life and remainder-man must apportion the fine between them according to the value of their respective interests. (1 Bro. C. C. 440; 9 Ves. 560.)

Trustees for sale, whether expressly such or by implication, have, in the absence of any express restriction on their powers, the right to use all reasonable discretion as to the time and manner of effecting a sale. They cannot be compelled to enter into any other covenant than that against incumbrances by their own acts. The general rule is, that a trustee for sale cannot become the purchaser of the trust property either for himself or as agent for another; and the *cestui que trust* is at liberty to set aside any such purchase, however fair, and though no advantage should have been gained by the trustee. (3 Ves. 750.) But a trustee is not absolutely prohibited from purchasing from the *cestui que trust* under certain circumstances, though the transaction is at all times one of great difficulty, and looked upon with great suspicion by the court. (9 Ves. 244.) Upon setting aside a purchase by a trustee, the court will in general allow for all repairs and improvements effected on the property. (11 Ves. 226.) The *cestui que trust* will not be entitled to relief unless he make his application within a reasonable time; and if while *sui juris,* and with full knowledge of his rights he expressly confirms the purchase, he will not be allowed afterwards to set it aside. (5 Ves. 680; 12 Ves. 355.)

IV. Of the powers of trustees.

The powers of trustees are either *general* or *special.* It is impossible to define exactly the general powers of trustees, the extent of which depends in each case upon the particular circumstances of the trust-estate. It may however be laid down as a general rule, that whatever is compellable by suit is equally valid if done by the trustee without suit (4 Ves. 369); though, if a suit has already been instituted for the execution of the trust, whereby the management is taken out of the hands of the trustee, he ought to take no step without the sanction of the court. (10 Ves. 104.)

V. Of allowances to trustees.

It is a settled rule that a trustee is not entitled to charge for his time and trouble in the management of the trust-estate, whether he be a professional person or not; and the rule applies not only to trustees expressly nominated, but to all persons bearing a fiduciary character, such as executors, mortgagees, receivers, and committees of lunatics' estates. (10 Ves. 103.) Exceptions to this rule have been admitted in the cases of trustees for the estates of absentees in the West Indies and executors in India; but the rule against such allowances to trustees is only a general one in the absence of express directions by the settlor to the contrary, and there is no objection to a trustee's receiving remuneration for his services, or to his being allowed to make professional charges, if the intention of the settlor to that effect be clearly expressed. (7 Ves. 480; 3 Beav. 338.) A trustee may even bargain with his *cestuis que trust* for an allowance, though bargains of this kind are very narrowly watched by the court. Trustees not being allowed to charge for their own trouble, may on proper occasions, and where the business of the trust is troublesome or complicated, call in the assistance of agents at the expense of the estate.

A trustee, though not allowed to charge for his trouble, is entitled to all his expenses out of pocket; and even a specific remuneration given by the settlor to the trustees is no reason for their not receiving an allowance for expenses. (7 Ves. 480.) The expenses incurred by a trustee in the management of the trust-estate are considered as a charge upon the estate, to the satisfaction of which the trustee is entitled before he can be compelled to convey.

The general rule with respect to the costs of trustees incurred in legal proceedings is, that they shall be allowed as between solicitor and client, if there be a fund under the control of the court out of which they may be paid. (1 Swanst. 201.) But this rule is subject to numerous exceptions, depending upon the circumstances of the case, and the propriety or otherwise of the conduct of the trustee, either in the course of the suit itself or in the matters out of which it arose. A trustee who disclaims by answer in chancery is entitled to costs as between party and party only. (2 M. & K. 278.)

VI. Of the relinquishment of office by trustees.

A trustee may be discharged from his office by the consent of the *cestuis que trust*, but for this purpose the consent of all must be obtained, however numerous they may be; and if any of the *cestuis que trust* be incompetent to consent, or be not yet *in esse* as in the case of a limitation to unborn children, no complete discharge can be obtained.

A trustee may be discharged in virtue of a special clause to that effect contained in the instrument under which he is trustee. A proviso to this effect is usually introduced into settlements combined with a power either to the *cestui que trust*, or to the co-trustees, to nominate a new trustee in the event of any of the number happening to die, or being desirous of being discharged from, or refusing or declining, or becoming incapable of acting in the trusts. The transfer of the trust is not complete until the new trustee has been nominated by the donee of the power, and a conveyance or assignment of the property has been executed. Powers of appointing new trustees are strictly construed, and cannot be properly exercised except under the precise circumstances contemplated in the power, and it is always considered that the original number of trustees ought to be maintained. For this reason it would be improper to appoint one trustee to do the duty of two retiring trustees (2 M. & K. 682); and where there is a direction that upon the trustees being reduced to a certain number others should be nominated by the survivors, it has been determined that they might supply vacancies before the numbers were so far reduced, but that then they were compellable to do so. (5 Ves. 825.)

Two recent acts, known as the "Trustee Relief Acts," have provided facilities for trustees wishing to discharge themselves from the responsibility of administering funds which may have come into their hands.

VII. Of the estate and rights of the *cestui que trust*.

1. As to what it consists of. In cases of the simple trust the whole rights of equitable ownership consist in the right of possession and the right of disposition.

The equitable owner has in general a right to the possession of the estate, but where there are several parties interested either contemporaneously or in succession, it is in the discretion of the court of equity to determine whether possession ought to remain with the trustee or be given up to the *cestui que trust*. The right of possession of the *cestui que trust* is recognised in a court of equity only, for at law the trustee is considered as the owner, and the *cestui que trust* as tenant at will only. The trustee as tenant of the legal estate may recover in ejectment from his own *cestui que trust*, who has no defence to the action at law, and is only entitled to apply for an injunction in equity. (8 T. R. 122; 1 B. & B. 445.)

Upon the ground that the *cestui que trust* is the beneficial owner of the estate, he is entitled, either by the express language or by the equitable construction of statutes, to various privileges connected with real estate. Thus the 2 Hen. V. st. 2, c. 3, and the subsequent statutes relating to persons entitled to serve as jurors, have been construed to apply to the *cestuis que trust*, and not to the trustee. By 7 & 8 Will. III. c. 25, s. 7, the right of voting as a freeholder of a county was conferred on the *cestui que trust*, if in possession; and by the 2 Will. IV. c. 45, s. 19, the *cestui que trust* of copyholds or of any lands whatever except freehold, of the required yearly value, is entitled to vote at elections of members of parliament whether in possession or not.

The *cestui que trust* of chattels is also entitled to the use and possession of them during the continuance of his interest; and upon this ground they do not, upon the bankruptcy of the tenant for life, fall under the rules as to goods in the order and disposition of the bankrupt with the consent of the true owner. (19 Ves. 491.)

A *cestui que trust* who is entitled to the whole equitable interest may, in virtue of the *jus disponendi*, call upon the trustee for a conveyance of the estate. But he has no such right when the trustee holds upon trust for the benefit of others, or even when he is entitled to the whole usufructuary interest, but the continuance of the estate in the trustee is necessary to answer some ulterior purpose relating to the trust, such as to preserve contingent remainders. (5 Mad. 429.)

In cases of special trust, the right of the *cestui que trust* is to have a specific execution of the intention of the settlor to the extent of that *cestui que trust's* interest. If there be but one *cestui que trust*, and he capable of consent, the specific execution of the trust may be departed from; and so where there are several *cestuis que trust*, who all agree; but no variation can be made so as to affect the interest of any *cestui que trust* without his consent.

2. Of the nature and properties of the estate of the *cestui que trust*.

Equitable interests may be assigned, and the assignee may, like the original *cestui que trust*, compel a conveyance from the trustee by bill in equity, without making the assignor a party. (3 Russ. 583.)

Femes covert entitled to equitable interests in lands and equitable tenants in tail, might, before the Fines and Recoveries Act (3 & 4 Will. IV. c. 74), have passed their equitable estates by those assurances, and may now do so under that act by the same modes of assurance and with the same formalities as if the estates were legal.

The purchaser of an equitable interest should take care to inquire of the trustee whether he has had notice of any prior incumbrance upon the equity of the vendor, which will give the purchaser a remedy against the trustee in case of his misrepresentation (10 Ves. 470); and the purchaser should also, upon the execution of the conveyance, give notice to the trustee of his own equitable title, whereby he will secure precedence of all prior incumbrances who have not given such notice. (3 Russ. 30.)

Equitable interests in property are transmissible by devise, and require the same solemnities as legal interests. (1 Vict. c. 26, s. 3.) Possession or receipt of the rents and profits of equitable estates is considered in equity equivalent to seisin at law, and adverse possession of the one is attended with the same effects on the title as disseisin of the other. (2 J. & W. 1, 153.)

A trust of freeholds or copyholds is subject to the courtesy of the husband, but was until lately exempt from dower and freebench: now, however, by the 3 & 4 Will. IV. c. 105, the title of dower attaches upon equitable in the same manner as upon legal estates, though subject in either case to be defeated by the alienation, devise, or other declaration of intention on the part of the husband.

The effect of marriage is the same upon equitable as upon legal interests, and therefore a husband may assign the trust of a term of years belonging to his wife, in the same manner that he may assign her chattels real at law. (9 Ves. 99.)

Judgment creditors have, by the Statute of Frauds, sec. 10, execution at law against the equitable freehold estate of a debtor in the hands of his trustee, when the debtor has the whole beneficial interest; but if he have a partial interest only, or the estate be not freehold, the judgment creditor has no execution at law, but he may in a court of equity obtain the same satisfaction out of the beneficial interest as he would be entitled to at law out of a legal estate. (4 Mad. 504.)

The estate of the *cestui que trust* is governed as to descent by the rules of the common law.

Trusts of chattel interests were always considered as assets in equity, but it was a question whether a trust of a freehold was assets in the hands of the heir until the Statute of Frauds, by the 10th section of which a trust in fee-simple was declared to be assets by descent, in the same manner as a legal estate. The enactment however applies to simple trusts only, and not to special trusts or equities of redemption (2 Atk. 293); but now, by the 3 & 4 Wm. IV. c. 104, all a persons' *estate or interest* in lands, tenements, or hereditaments, corporeal or incorporeal, or other real estate, whether "freehold, customaryhold, or copyhold" (which words apply equally to legal and equitable estates), are made assets for the payment of debts as well by simple contract as on specialty. Trusts of chattel interests will be legal assets in the hands of the executor. (Mod. 858; 4 Ves. 541.) Simple trusts of real estate are made legal assets by the above-mentioned section of the Statute of Frauds; and it seems that complicated trusts and equities of redemption, which are not within the statute, will be considered legal assets as to specialty creditors by analogy to law. (2 'Ch. Rep.' 143.) It appears that under the 3 & 4 Wm. IV. c. 104, real estates are, with respect to simple contract debts, to be taken as equitable assets, but that the act does not alter the mode of administration of trusts of chattels nor of equitable freehold interests, in so far as they were assets before the act.

3. It is a maxim of equity that a trust shall not fail for want of a trustee. If the intention of the settlor be clear, but he has omitted to name a trustee, or the trustee dies or becomes incapable of taking the estate, the trust attaches upon the person on whom the legal estate has devolved. (Wilm. 21, 22.) When powers given to trustees are not discretionary, but imperative, they are, as above mentioned, considered as trusts, and the court will protect the *cestui que trust* from the failure or neglect of the donee of the power. Where the discretion of the trustee was to be governed by a rule which the court can apply, it will do so; but where there is no rule or measure by which the discretion of the trustee was to be governed, the court executes the power in the manner which appears most reasonable, and in general proceeds upon the principle that equality is equity. (2 Ed. 332; 'Eq. Ca. Ab.' 194.) Where a discretion is given to the trustee in respect of the objects to whom an appointment is to be made, questions sometimes arise, when the power comes to be executed by the court, as to the objects to be included and the mode of distribution. When the power is in favour of "relations," the court, except under particular circumstances, appoints to relations within the statute of distributions, when it seems that the distribution will be made *per capita*, and not *per stirpes* (1 Bro. C. C. 33); and the words "next of kin" occurring in such a power are settled to mean "nearest of kin," to the exclusion of those who would take by representation under the statute. (2 M. & K. 780.)

4. The *cestui que trust* is entitled to have the administration of the trust-estate placed in proper hands. Thus the court will dismiss a trustee upon its being shown, upon application by bill to the Court of Chancery, that he has acted improperly, or has become incapable of executing his office (4 Ves. 592; 5 Ves. 707); and where the original number of trustees has been diminished, the *cestui que trust* may have the vacancies supplied. (5 Ves. 772.) The *cestui que trust* may also file a bill against his trustee, either for the purpose of compelling him to the execution of an act of duty, or to restrain him from doing any act not within the scope of the trust, or which would be prejudicial to the estate. (1 Bro. 'C. C.' 177; 6 Mad. 10.)

5. If a trustee aliens the trust-estate, the *cestui que trust* may follow the estate into the hands of any person who has acquired it, whether he had notice of the trust or not; and even into the hands of a purchaser for valuable consideration, if he had notice at the time of his purchase. The limit of time and extent within which the *cestui que trust* may institute proceedings for the recovery of his estate is fixed by the 3 & 4 Will. IV. c. 27.

In case of a breach of duty by the trustee, the *cestui que trust* has also a remedy against him personally by way of compensation. The amount of the loss is considered as a simple contract debt against the estate of the trustee, and payment of it may be enforced in the same manner as for any other similar debt. The circumstance of the trustee having derived advantage or not from the breach of trust, makes no difference as to his liability. Where trustees are jointly implicated, it was formerly thought that the *cestui que trust* might proceed against any of them singly; but the contrary has since been settled. (8 Sim. 219.) But the *cestui que trust* will not be entitled to any remedy against his trustee, if he himself, being under no legal incapacity, has concurred in the breach of trust, or subsequently acquiesced in it, or *à fortiori* if he has executed a formal release to the trustee. (3 Swanst. 64.)

Owing to the inadequacy of the law to meet the case of defalcations and frauds of trustees, bankers, and other persons entrusted with the care and management of the property of others, a statute was passed (20 & 21 Vict. c. 54) whereby offences of this kind were made misdemeanours punishable with penal servitude for three years, or imprisonment not exceeding two years, with or without hard labour.

VIII. There are two rules of equity with respect to trust-estates which are of very general application. The first is, that what the settlor has directed to be done shall be considered as done; so that it shall not be in the power of trustees, by neglecting the performance of their duty, to affect in any way the interests of the *cestuis que trust*. Thus where money is directed to be laid out in land, or land is directed to be sold, equity will consider the conversion to have taken place, and deal with the property accordingly. This constructive conversion, however, subsists only until a *cestui que trust*, competent both from interest and personal capacity to elect, declares his intention as to the character in which he will take the property. [Election.]

The second rule, which is almost a consequence of the first, is, that no act of the trustee shall alter the nature of the *cestui que trust's* estate. This rule, of course, is to be understood only of acts not authorised by the trust; and with respect to *cestuis que trust*, who are *sui juris*, is universal, but is subject to some exceptions with respect to trust-estates belonging to lunatics. The court, though it will not in general alter the condition of the lunatic's property to the prejudice of his representatives, will not refuse to do so if it appear to be clearly for the benefit of the lunatic himself. (2 Ves. Jun. 72.) It was formerly thought that the court might exercise a similar discretion with respect to the estates of infants, but it is now settled otherwise. (19 Ves. 122.)

(Sanders, 'On Uses and Trusts;' Lewin's 'Law of Trusts and Trustees.')

TRUSTS, CHARITABLE. [Uses, Charitable.]

TRYTYLENE. [Propylene.]

TUBE. The surface of a tube is generally a cylinder, but this word may be made use of in mathematics. When a tube is bent, there is no distinct geometrical name for its surface, but the following definition might do very well: Let a surface be called a tube when it is formed by a circle which moves with its centre upon a given curve, and its plane always perpendicular to the tangent of that curve. This would include the straight tube, or common circular cylinder, and every species of bent tube.

TUBE-DRAWING. There are certain peculiarities in the fabrication of metal tubes which place them in a separate rank from other manufactures in metal.

Some varieties of lead-pipe are produced by casting a thick cylinder, of which the internal bore corresponds with the intended bore of the pipe, and then reducing the external diameter by drawing through a series of dies, smaller and smaller as the process proceeds, as described in Lead Manufacture. Mr. Hick has devised a mode of making *tapering* tubes; that is, tubes which taper or diminish in diameter from one end to the other. They are first made parallel or cylindrical and are tapered afterwards; the machine employed effects this by rotating grooved rollers; and a greater or less degree of taper is obtained by varying the proportion between the rate at which the tube is drawn through the machine and that at which the rollers revolve. The tubes for many locomotives are made in this way, taper within and cylindrical on the outside; the metal is cast hollow, and is drawn on a taper mandril through a plate; when used, the thick end is placed nearest to the fire-box. One of the early ways of making wrought iron tubes was to provide a strip of sheet iron, and beat it up by hand hammers and swages nearly to a cylindrical form; this was then laid in a semi-cylindrical cavity, with a mandril running through it; and then many blows were given by a heavy tilt-hammer, the lower face of which had a hemispherical or rather semi-cylindrical form. An improvement upon this was to draw the tube through grooved rollers after having been thus far fashioned. Another mode afterwards adopted was that of raising a strip of iron to a welding heat; beating up one end of it nearly to a cylindrical form; drawing the whole piece through a kind of tongs having bell-shaped jaws; and welding without the aid of any mandril. This method has been found available for tubes up to six inches diameter. Common brass tubes are often made by beating a strip of brass round into a cylindrical form, soldering the edges, and drawing it through holes to make the exterior true; without paying much regard to the interior. Telescope tubes, &c. are drawn inside and out, and are hardened at the same time; the soldered tube, being placed upon a steel mandril, is drawn through a draw-plate, by which the tube is lengthened, pressed everywhere close to the mandril, and rendered smooth and dense. Fluted tubes for pencil-cases are drawn through a fluted hole, upon a mandril usually cylindrical. Very small tubes, used by silversmiths, are drawn upon steel wire as a mandril. Many kinds of brass tubes are made exactly in the same way as the lead pipes described in Lead Manufacture; that is, by casting a thick cylinder, and then drawing it by machinery through a series of holes, smaller and smaller in regular order, so as to elongate the thick cylinder into a thin tube. Mr. Muntz patented a few years ago a process for making tubes of the *Muntz metal* introduced by him, which metal consists of about 2 parts of zinc to 3 of copper. A short thick tube is cast, and is then rolled out to a great length and reduced thickness; but having no mandril within it, it is squeezed flat; the proper shape is afterwards given to it by drawing through a circular hole. There is something in the quality of the metal which enables it to be elongated in this way, inapplicable to most other kinds. Mr. Webster, of Birmingham, has a curious method of making elastic metal tubes, suitable for forming the junctions of pipes exposed to variable temperature; or of pipes which are otherwise strained or required to bend, such as the tube-couplings connecting locomotives with their tenders, hose with fire-engines, or the like. The tubes are made with transverse corrugations, so as to yield to slight bendings, contractions, &c. Each corrugation is very narrow and deep. A plain tube is made first, and is then corrugated by degrees; this is effected by rolling, the rollers successively used being gradually deeper and deeper in their grooves, until the exterior of the tube is well puckered. Such a tube may be stretched, contracted, or bent within certain limits, without injury to its strength or soundness; they imitate in a humble way the snake-like structure. Triangular and rectangular tubes are much used in France for sliding scales and measures; these are made nearly in the same way as ordinary cylindrical tubes, the sectional form being dependent on the draw-hole and the mandril. The small collapsible colour-tubes, so much used by artists, were at first made like common brass and lead pipes, by successively drawing a thick tube till it becomes very long and very thin; but they are now made more quickly by a peculiar kind of stamping, only possible with such a soft metal as tin. Mr. Ritchie has devised a mode of making tubes thicker at the middle than the ends, by giving them a reciprocating motion between rollers, half way through and back again.

Plans have been devised for making copper tubes by electro-deposit. The method will be understood from the principles explained under Electro-Metallurgy.

TUBERCLE is the name given to that form of deposit which is observed in the tissue previous to scrofulous ulceration [Scrofula], and also in the lungs when they are affected with phthisis [Phthisis] or pulmonary consumption.

TUBERCULOSIS. [Scrofula.]

TUBULAR BEAMS. In addition to what has been said on the subject of the resistance of hollow girders, [under Girders and Resistance], it may be desirable to state that the investigations by Mr. Tait of the experiments made by Mr. Fairbairn have led to the recognition of the following laws upon the subject:—1. The strength varies nearly as the area of the top, or of the bottom flange, multiplied by the depth, divided by the distance between the points of support, and affected by a coefficient determined by experiment. 2. When the depth and distance between the points of support are the same, the breaking weights are as the areas of the top, or of the bottom parts. Mr. Tait gives, as the practical formula derived from these laws; calling w the breaking weight of a rectangular tubular beam; *a*, the area of the bottom web; *d*, the depth of the beam; *l*, the clear bearing, and *c*, a coefficient found to be equal to 18 tons; all the dimensions being in inches; then $w=\frac{c\,a\,d}{l}$. 3. In hollow cylindrical beams formed of thin plates, the breaking weight in tons is equal to the continued product of the sectional area, by the depth, and by a constant (14½ tons), divided by the distance between the supports; and Mr. Tait asserts that square tubular beams possess 1⅓ times the strength of cylindrical ones: if this be correct, rectangular cells at the top of a large tubular girder are preferable to circular ones. 4. In hollow elliptical beams the breaking weight in tons is equal to the continued product of the sectional area, the depth and a constant (15 tons) divided by the distance between the supports: all these dimensions being, as before, in inches. The formula becomes of course, with the change in the value of the coefficients, the same as above, $w=\frac{c\,a\,d}{l}$; and as it is so much easier in rectangular beams to modify the area of the bottom flange, so as to ensure in it the requisite ratio between it and the top flange, there must evidently be an advantage in their use.

The tubular girders for beams of wrought iron appear to have been used on a large scale, for the first time, in the bridge over the turnpike road at Blackburn, by Mr. William Fairbairn; since that period, the system has been extended by other engineers in a most extraordinary manner, as in the instances of the Britannia and of the Saltash bridges; and at the present day the tubular wrought iron beams are very often substituted for the cast iron girders which were, previously so much used in general construction. In the latter case, the superior lightness of the wrought iron tubular girders, and their greater powers of elasticity, render them preferable to the weightier, and more brittle and uncertain, cast iron; but the wrought iron tubes do not admit of artistic treating in the same manner that cast iron ones do, and therefore are less fitted for picturesque structures. The works of Messrs. Hodgkinson, Tate, Clark, Fairbairn, Morin, Love, &c. must be consulted by the student of this branch of the arts of construction; and in the 'Annales des Ponts et Chaussées,' and in the 'Journal des Travaux Publique de la Belgique,' may also be found some interesting, practical, and theoretical articles on the subject. The Swiss and American engineers have for many years used species of tubular girders in their timber bridges of large span; but these were designed upon the ordinary principles of carpentry as applied to ordinary framing, and did not depend for their strength in any important manner upon the cross bracing and roof which converted them virtually into tubular beams.

TUCA'NUS (the Toucan). A southern constellation of Bayer, situated between Phœnix and the south pole, and near to the bright star in Eridanus. The following are the principal stars in this constellation:—

Character.	No. in Catalogue of Lacaille.	No. in Catalogue of British Association.	Magnitude.
α	9074	7767	3
γ	9420	8098	4
β^1	119	127	4
β^2	120	128	4

TUESDAY. [Week.]

TULIP. Of all the plants which have obtained attention on account of the beauty of their flowers, perhaps tulips have had the most. In estimating the excellence of a particular flower, the florist is not so much guided by its beauty of form and colouring as by its rarity; and sorts which have at one time obtained great prices on account of their rarity have become little thought of when they became more abundant. There are, however, several points considered by florists as essential to the character of a fine tulip. "The stem should be strong, elastic, and erect, and about 30 inches above the surface of the bed. The flowers should be large, and composed of six petals (*phylli*): these should proceed a little horizontally at first, and then turn upwards, forming almost a perfect cup, with a round bottom, rather widest at the top. The three exterior petals should be rather larger than the three interior ones, and broader at their base: all the petals should have perfectly entire edges, free from notch or serrature; the top of each should be broad and well rounded; the ground colour of the flower, at the bottom of the cup, should be clear white or yellow, and the various rich-coloured stripes, which are the principal ornament of a fine tulip, should be regular, bold, and distinct on the margin, and terminate in fine broken points elegantly feathered or pencilled. The centre of each leaf or petal should contain one or more bold blotches or stripes, intermixed with small portions of the original or breeder colour, abruptly broken into many irregular obtuse points." ('Cyc. of Gard.') For the botanical character, see Tulipa in Nat. Hist. Div.

The varieties of cultivated tulips have been divided by florists in many ways for the sake of convenience. Parkinson, who wrote in 1629, enumerates 140 varieties, which were divided into *præcoces*, early blowers; *sertinæ*, late blowers; and *dubiæ mediæ*, doubtful or middle blowers. The first division consisted principally of varieties of *Tulipa suaveolens*; the latter divisions were chiefly composed of varieties of *T. Gesneriana*. Amongst modern florists in Great Britain, the varieties of the latter tulip, of which upwards of 600 are enumerated in modern catalogues, are divided into four families—Bizarres, Byblœmens, Roses, and Selfs.

Bizarre tulips have a yellow ground marked with purple or scarlet of different shades. *Byblœmen tulips* have a white ground, lined, marked, striped, or variegated with violet or purple only of various shades. *Rose tulips* are marked or variegated with rose, scarlet, crimson, or cherry colour on a white ground. *Selfs*, or *plain-coloured tulips*, are those which have a white or yellow ground without any marks. The first three of these families are again divided into *feathered* and *flamed*, according as the intermingled colours are in narrow stripes or pencillings, or in a broad central stripe.

It is from amongst the last family of tulips, the *Selfs*, that what are called *breeders* are selected. In a state of nature the tulip is mostly a self, that is, it has but one colour; but under certain circumstances all the other colours that are found in tulips will be developed in these simple-coloured tulips. It is thus that the last variety of tulips has been obtained that at present exists; and as each variety can be propagated by offshoots from the parent bulb, and as the colours of tulips will admit of an infinity of modes of blending, there is hardly a limit to the number of varieties of these flowers which may be obtained. Selfs are always raised from seeds, but the circumstances which are most favourable to the "breaking" of the Selfs, as the development of other colours is called, are not well understood. A florist will have to wait sometimes twenty years without having the pleasure of seeing his Self "break."

To develope all the beauty of form and colour of which the tulip is susceptible, requires the greatest care in its cultivation, and perhaps it is only amongst the amateurs of Holland and Belgium that this flower can be seen in all its glory. Tulips are mostly planted in beds, which should be made in an open, airy situation. A bed of tulips is planted in what are technically called *rows*, consisting uniformly of seven, arranged with regard to the harmony of their colours, the tallest occupying the centre, and the bed may be thus of any length, while the row always consists of seven. The soil should be dug out for about 20 inches deep, and the bed filled in with a mixture of about two parts of a fresh, rich, loamy soil, rather of a sandy character, and one part of well-rotted cow-dung. The best time for planting the bulbs is from the end of October to about the 10th of November. They should be planted about seven inches apart, and about four inches deep, or less according to their size, in the ground. The leaves will appear in February, and the blossoms in April or May. The bed of flowers should be protected by an awning, which must not be used till the flowers are opened, and should be so constructed that the light and air may be freely admitted during the intervals between the coolness of the night and the brightness of the sun at noonday. Tulips should never be artificially watered. When the petals fall off, the seed-vessel should be removed, as its remaining on weakens the bulb. When the top of the stem begins to wither and dry up, and the leaves become brown, the bulbs should be taken up and placed in a dry situation. In the following August or September the loose skins and fibres and the easily separable offsets should be taken off the bulbs, and they should be deposited in drawers. In propagating the tulip from seeds, they should be sown in deep boxes, filled with good garden-mould mixed with sand. The young plants will not require water, and they may be expected to blossom by the fourth or fifth year, or at latest the seventh.

(Loudon, *Cyclopædia of Plants*; *Cyclopædia of Gardening*; MacIntosh's *Book of the Garden*; *Diction. des Sciences Naturelles*; Paxton's *Botanical Dictionary*; Redouté, *Liliacées*; Hogg, *Supp. to Practical Treatise*, &c.)

TUMBREL, or TUMBRIL, a machine formerly used for the punishment of scolding women, consisting of a stool or chair attached to the end of a long pole, mounted in such a manner that the chair, with the offender placed in it, might be swung over a pond, and immersed as often as might be necessary. Several notices of the use of this apparatus, which was also called a *trebuchet*, a *cucking-stool*, or a *ducking-stool*, are given in Brand's 'Popular Antiquities,' art. 'Cucking-stool.' It appears to have been used as early as the era of the Saxon government in England, and to have been a common punishment in some places at least as late as the time of Gay, who mentions it in his 'Pastorals.' The tumbrel was also used as a punishment for brewers and bakers who transgressed the laws relating to them. Fabian (quoted in Strutt's 'Horda Angel-cynnan,' vol. ii., p. 9) says that, in the 42nd year of Henry III., bakers were, for "lack of size," punished by the *tomberell*, whereas before that time they used to be punished by the pillory; and he adds, that the tomberell was "a kind of pillorye, made foure-square, that turned round about." The name tumbril is also applied to the covered carts used to carry tools, &c., in a train of artillery.

TUMOUR. It is not possible to define exactly the diseases which are commonly classed under the name of Tumours, and any definition in which the character of *swelling* (which is the true meaning of tumour) is included is unnatural; for there are several diseases which agree in the most important respects with some of those called tumours, but are not attended by any obvious enlargement or swelling of the part in which they are situated; and the same disease exists in some cases with and in others without swelling. The greater part of the diseases which have been classed as tumours are examples of a large class of what may be called morbid or parasitic growths; diseased structures, which are not mere alterations of previously existing parts, but new organisms or living substances which have grown within the tissues of the body by powers of development peculiar to themselves, and which depend upon the surrounding parts only for their supply of blood or other nutritive fluid. In this class are included all those diseases described as solid or sarcomatous tumours, and those which are closely related to some kinds of tumours, but are not accompanied by swelling, such as tubercle, certain forms of diffused cancerous growths, and some others.

The diseases called Encysted Tumours are entirely different from all others of the class in their pathological characters, and are considered in a separate article. [WEN.] The chief cancerous growths are treated of under their appropriate heading [CANCER; MELANOSIS]; and tuberculous growths under the name of the disease which is consequent on their development [PHTHISIS; SCROFULA]. The present article will be chiefly devoted to the history of those morbid growths which are commonly described as innocent tumours.

All morbid parasitic growths may be divided into *malignant* and *innocent*. The practical distinction between the two classes, from which they derive their names, is that an innocent growth or tumour is not likely to recur after being removed by operation, but a malignant growth is likely to recur in the same or some other part. These two names may safely be retained to mark the two chief divisions of morbid growths; for although the test of the result of a surgical operation cannot be applied to those which from their locality do not admit of extirpation, yet the names indicate important characteristics in the progress of the two kinds of growth, wherever seated. Independently of the practical distinction, the most essential characters of malignant growths are:—1. That they may occur in almost any part of the body, although some parts are more liable than others, and each kind of growth seems to find its most appropriate seat in a certain organ, as cancer in the breast, tubercle in the lungs, melanosis in the liver, &c. 2. That they have a tendency to infect the adjacent parts, and to propagate themselves from one part to another, probably by germs carried from the primary disease into the blood, with which they circulate till they meet with an organ in a fit state to supply them with the means of increase. 3. That they tend, through an intermediate process of softening (which appears to be consequent on the death of their constituent particles), towards ulceration; that this ulceration is of a kind which is at present incurable; and that in its progress it involves almost without distinction of tissue all the adjacent natural structures of the body, the particles of which, by their contact or combination with those of the malignant growth, seem first to assume a nature similar to their nature, and then to perish with them. 4. That in general the minute structures of which they are composed are dissimilar to those of the natural organs of the body; and that their development does not proceed to the formation of any structure similar to the fully developed tissues.

The distinctive characters of innocent growths are chiefly negative. Certain of them may present one, but they rarely present more than one, and never all, of the characters just described. Thus:—1. The number of tissues in which innocent growths occur is comparatively few: in many parts in which malignant growths are common they are never seen; and when, as sometimes happens, many innocent tumours exist in the same body, they are (at least as a general rule) all found in the same tissue, or in or near the same organ. Thus, many fatty tumours may grow at the same time, but they all lie in the tissue of the natural fat: many fibrous tumours may occur together, but all are in or near the uterus. On the contrary, when many cancerous growths co-exist, they are commonly found in many different organs and tissues. 2. The tissues adjacent to innocent growths are not further altered than in consequence of the pressure and the inflammation which the growth excites; neither is there any evidence that such growths propagate themselves from one part to another. 3. Innocent growths have no natural tendency to ulcerate or slough; those changes happen to them only in the same manner and under the same circumstances as to the natural tissues of the body. Moreover, in ulcerating or sloughing they have no more tendency than the natural tissues in similar conditions have to involve the adjacent parts in their destruction. 4. The tissue of an innocent growth is in general similar to that of some natural and fully-developed tissue of the body.

The class of innocent growths includes most of those to which the name of Sarcoma is now commonly given. Their appearances are so various, that the most practised morbid anatomists frequently meet with examples which they cannot certainly refer to any described variety: yet there are some well-characterised forms, within the descriptions of which may be included a great majority of those which occur in the human body; and these we shall describe under the names of the Fatty Tumour, or Growth; the Cellular; the Fibrous, or Tendinous; the Cartilaginous; the Osseous; the Fibro-cartilaginous.

The Fatty or Adipose Tumour, to which the name of Lipoma is often given, is the most common of all the tumours occurring in the human body, and, happily, the most innocent, and the most usually capable of remedy by extirpation. Its general seat is in the subcutaneous cellular adipose tissue; but in rare cases it is situated more deeply, and then has a more compact structure and more intimate connection with the surrounding parts. It usually occurs singly; but sometimes twenty or more of various small sizes are seen in the same person. Its elementary tissue is exactly like that of the fat in which it lies, but from which it is separated by a layer of compact cellular tissue, and is generally distinguished by the smallness and distinctness of the lobes composing it. Its blood-vessels are few and of small size, and usually enter it at its base, where it is more closely than elsewhere connected with the adjacent tissues. It is insensible, and commonly grows very slowly, without producing pain, or any other inconvenience than is due to its weight or its pressure on adjacent parts. When left to itself, the adipose tumour may grow to an enormous size. Mr. Copeland removed one weighing 22 lbs.; Sir Astley Cooper, one of 37 lbs. 10 ozs.; and M. Dagorn of Morlaix, one which weighed 46 French pounds. The size of the wound necessarily made in the removal of tumours of such magnitude renders the operation somewhat dangerous; but, except for this circumstance, the extirpation of fatty tumours may usually be undertaken with full confidence of success. If not removed, they are apt, through the distension and thinning of the skin over them, to give rise to ulceration and other more painful affections.

The Cellular Tumour, which derives its name from the similarity of its tissue to that of the common cellular tissue of the body, is a very rare disease. It is composed of a compact substance, infiltrated by a serous or half-gelatinous fluid, and may attain a great size. Mr. Lawrence, in his 'Lectures on Surgery,' has described the best example yet known of it: perhaps also the disease which Mr. Abernethy, in his 'Classification of Tumours,' named Common or Vascular Sarcoma, was of this kind. But altogether very little is known of this form of tumour: the great enlargements of the skin of the scrotum, supposed by some to be of the same nature, are widely different from it.

The Fibrous or Tendinous Tumour (the fleshy tubercle of Dr. Baillie) is a very frequent and well-marked growth. Its ordinary, perhaps its only, seat is in the walls or in the neighbourhood of the uterus. Its natural form is almost exactly globular; but when it hangs in a dependent position it generally becomes pyriform. Its tissue has the same microscopic character as that of the natural fibrous and tendinous tissues, and is equally little vascular. Its section presents a very compact and firm semi-transparent basis, intersected by numerous shining, tough, fibrous fasciculi, arranged sometimes in rays proceeding from its centre, but more frequently in irregularly arched and undulating lines. It grows slowly, and at first without pain; but when it has attained some size it usually excites painful and dangerous affections of the uterus; and this is especially the case when the tumour projects into the cavity of that organ. One such tumour may grow alone in the uterus; but more commonly two or more grow together, and sometimes there are from ten to twenty. They may increase so as to form masses nearly a foot in diameter, and in this case they usually end fatally by their pressure on important organs, or by hæmorrhage when they project externally. In advanced stages of their growth, or at any time if they cease to increase in size, they are apt to be calcified; earthy matter being deposited around or within them, so as to form a shell or a coral-like mass of hard substance, which bears some resemblance to ivory, but has none of its microscopic characters.

The Cartilaginous Tumour is that which has been named Chondroid or Cartilaginous Sarcoma: it is the Enchondroma of Müller, and one of the numerous forms of growths which have been heaped together under the term osteo-sarcoma. Its usual, and perhaps its only, place of growth is within or upon the bones, and it occurs in connection with the bones of the fingers and the last phalanx of the great toe more frequently than in any other part. It grows slowly, and usually without any pain, and may continue to increase for thirty or more years. It is most commonly isolated, but sometimes two or more tumours of the same kind occur on one or both hands. The most usual form of the cartilaginous tumour is globular, with an irregular nodulated surface; and a section shows that it is composed of numerous round masses of a grayish-white semi-transparent substance, closely resembling the cartilage composing the skeletons of cartilaginous fishes, and presenting all the microscopic characters of ordinary fœtal cartilage. The component masses, which are especially obvious when the tumour is large, vary in size from two lines to half an inch in diameter, and in different specimens vary much in consistence: they are held together by portions of tough fibro-cellular tissue, in which blood-vessels run, but are themselves little, if at all, vascular before the process of ossification has commenced in them.

The cartilaginous tumour may grow to an enormous size: one in the College of Surgeons, which had almost completely ossified, measures a yard in circumference. It is situated on the upper part of the tibia. But even in the most advanced states they may be removed by the amputation of the part on which they are situated, without fear of their recurring; and this is always an advisable proceeding: for besides the inconvenience produced by their weight and pressure on adjacent parts, large cartilaginous or osseous tumours are apt to produce ulceration and sloughing by their distension of the skin which covers them.

The greater number of those called Osseous Tumours, or osseous exostoses, are only ossified cartilaginous tumours,—examples of what may be called the second stage of the disease last described. It is doubtful indeed whether any tumour possessing the true osseous microscopic structure is formed except through a preceding cartilaginous state. Many other kinds of tumours connected with bones are incorrectly called osseous or osteo-sarcomatous. Such are those connected with medullary or soft cancerous diseases, of which some are only the osseous skeletons upon which the malignant disease was fixed; others are the remains of the original bone expanded and broken out by the growth of the malignant disease in the interstices of its tissue. And again, other hard tumours connected with bones result from what should be called the calcification rather than the ossification of a previous softer growth: for in these the earthy matter is deposited irregularly, and they never acquire the structure of true bone. Most or all of these calcified tumours are of a malignant nature. One of the best characterised forms is that of which Dr. Baillie ('Morbid Anatomy') gives the history, in a case in which, after Mr. Hunter had amputated the patient's leg, calcareous masses, similar to that which had formed within and around the femur, were developed within the lungs and upon the ribs.

The history of the Fibro-cartilaginous Tumour is as yet more imperfect than that of any of the preceding, except the cellular. It is most frequently, or always, connected with the bones, and is most commonly met with upon the jaws, from which it may be removed without fear of recurrence. It has usually a round or oval form, and its surface is less deeply nodulated than that of the cartilaginous tumour. It may attain a great size, and commonly leads to sloughing and ulceration of the tissues over it, if not timely removed. It is composed of a very firm, compact, pale, whitish or yellowish, albuminous tissue, in which small spicula of bone are often scattered, but which does not become truly or entirely osseous. It may grow within a bone, but more usually it commences on its exterior: in the former case it generally expands the shaft or body of the bone into a shell around it; in the latter the surface of the bone is broken up, and seems to coalesce with the tissue of the tumour.

In different examples the fibro-cartilaginous tumour presents various degrees of consistence, and not a few apparent diversities of internal structure. In some examples its substance is homogeneous, in others obscurely fibrous; and from these last, which are the most frequent, it derives its name, which is intended to express its general aspect rather than its minute structure, for the firm tissue of which it is chiefly composed has not the microscopic or chemical characters of cartilage. In other examples again the fibrous structure rather predominates over that which resembles cartilage; and in others numerous cells, containing a glairy or a serous fluid, are scattered through the interior of the mass. From the existence of such diversities, it is not unlikely that more than one kind of tumour is included in this name; but the gradations, from the examples in which the tissue is most nearly homogeneous to those in which it is most fibrous, or contains most cells, are so numerous and gradual, that it seems more probable that they are all of one kind, modified by accidental circumstances, or examined in different stages of their development.

The treatment of the tumours whose natural history has been described may be summed up in a few words. There is no remedy for them but their removal: not one of the medicines proposed for exciting their absorption is worthy of a trial. Of the means of removing them (when removal is possible), none is so safe, so expeditious, or productive of so little pain or inconvenience, as the knife; and whenever it can be employed, the sooner it is used the better, for, in general, delay can only increase the severity of the operation. For the operation itself, the only general rule is, that the whole of the diseased mass must be removed; any portion which is left will most probably become the nucleus of a similar growth. The particular proceedings must be varied according to the size, locality, and other circumstances of the tumour.

TU'MULUS (or Barrow), a Latin word, signifying a "little hill." Tumuli, or artificial mounds of earth, of various sizes and forms, are found in many parts of the globe, and are for the most part tombs, or sepulchral memorials of persons of distinction, or of warriors slain in battle. That some of these artificial mounds were originally raised for, or at least appropriated to, other objects than that of sepulture, is probable; but of this we have no satisfactory evidence. We limit our present remarks to the consideration of tumuli as sepulchral monuments.

In the book of Joshua mention is made of heaps of stones [Cairns] raised over dead persons, which in course of time would assume nearly the appearance of barrows at the present day. This practice seems, however, to have been done in the case of enemies only, and was doubtless intended as a mark of abhorrence. The earliest account of tumuli as honorary memorials of the dead is by Homer. His descriptions of the funerals of Patroclus and of Hector, in the 'Iliad,' differ in very trifling particulars; but in each the same mode of inhumation is commemorated. The ceremony of burning the body took place during the night, and at the dawn the embers were quenched with wine. The ashes of the deceased were inclosed in an urn, placed near the centre of the space occupied by the pyre, which was surrounded by an artificial substructure, or a foundation, and the loose earth was heaped above it. The word used by Homer to denote the throwing up of such loose earth (χεύω) is strikingly picturesque; and its propriety will be readily acknowledged by persons who have seen the outline of many of those primitive sepulchres, which has evidently resulted from the loose earth being allowed to settle at the angle which it would form when thrown up.

In later ages we find accounts of immense sepulchral tumuli. Such was that of Alyattes, the father of Crœsus, which is described by Herodotus and by Strabo. A sepulchral mound which still exists near the site of Acanthus was raised by the army of Xerxes, in memory of a noble Persian who had superintended the construction of the canal which was cut across the isthmus of Athos.

Tacitus, from whom we derive the first satisfactory account of the Germans, observes that their funerals were distinguished by no empty pomp. "The bodies of illustrious men were consumed with a particular kind of wood; but the funeral pile was neither strewed with costly garments nor enriched with fragrant spices. The arms of the deceased were committed to the flames, and sometimes even his horse. A mound of earth was then raised to his memory, as a better sepulchre than those elaborate structures which, while they indicate the weakness of human vanity, are at best but a burthen to the dead." ('Germania,' xxvii.)

Whether the body was preserved entire or committed to the flames, the custom of depositing the remains of dead bodies under a mound of earth has been observed in nearly every part of the world; by the ancient Scythians on the banks of the Borysthenes (Herod., iv. 71), and by the aborigines of North America on the banks of the Ohio and Mississippi (Jefferson, 'Notes on the State of Virginia'; Squire and Davis, 'Ancient Monuments of the Mississippi Valley,'); and such mounds are still to be seen in great numbers in Denmark, Sweden, Germany, France, Spain, Portugal, and Great Britain.

Of the sepulchres of the Scythian nations, many are found in the Kuban. They are described as perfect tumuli, sometimes of great height, on a base formed by a square wall of large stones. In some cases the earth is excavated to a considerable depth; in others it merely covers the body. The deposits, with the remains of the dead, are weapons and implements of war, domestic utensils, and idols.

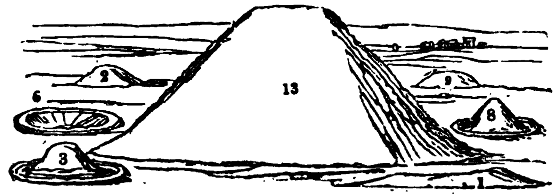
Vast numbers of the tumuli scattered over various parts of Germany have been examined. They have been distributed by the antiquaries of that country into four classes:—1. Tumuli without bodies, or urns. 2. Tumuli with bodies, but without urns. 3. Tumuli without bodies, but with urns baked. 4. Tumuli with both bodies and urns. Of the last class, several were opened in the neighbourhood of Sinzheim, and skeletons were found in them, with rings of brass and iron about the arms, feet, and fingers, ear-rings, and chain or other ornament surrounding the neck. (Meidinger, 'Die Deutschen Volkstämme geographisch und geschichtlich belaüchtet,' p. 208, &c.) Mr. Kemble, who "opened at least three thousand interments in North Germany," and found in the whole only two skeletons, whilst in another part (Sinzheim) he found in 14 barrows, "70 interments and not one sure case of cremation," thinks that the appearance of the barrows hitherto opened proves that the custom of cremation was at one time general among all the Teutonic races, and that it only slowly disappeared before the progress of Christianity, which imposed the practice of burying the bodies of the dead unburnt. For a time it seems to have been usual to inter the unburnt bodies in the tribal inclosures, and even to open, for their reception, the old barrows to which family and other associations had given a kind of sanctity. This custom seems to have continued as low down into Christian times as the 7th century, and in many places much later, but eventually the custom became universal among the German races to inter their dead within the precincts of their churches, and hence every churchyard became a place of sepulture. We have quoted above Tacitus's description of the ancient German manner of burning and burying the dead; and there can be little doubt, from the appearances presented by the major part of the more conspicuous barrows which have been opened that, at least as regards distinguished persons, his account is sufficiently accurate; but Mr. Kemble, who investigated this point with great zeal and diligence, has shown that one and perhaps the ordinary mode was to burn the body upon a stone structure raised for the purpose. As the result of numerous explorations of previously unopened barrows, and a comparison of passages and allusions in old German and Scandinavian literature, he infers that "a heap of stones was built, having a hollow for the body; the materials for a fire were laid in this, and the stones made red-hot, and then the corpse placed in the trough, and covered over with combustible materials till all was consumed. The hollow was then filled up with more stones, and the whole surmounted with earth to form a barrow." ('Archæological Journal,' vol. xiv.)

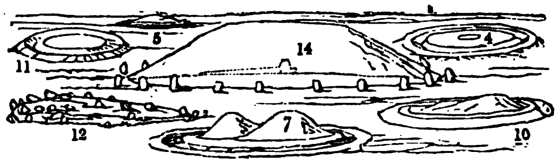
Of late years great attention has been paid by the northern antiquaries to the primeval remains of Denmark, Sweden, and Norway, and the barrows of those countries have been carefully and systematically explored. Along with certain local peculiarities they bear a general resemblance to the barrows occurring throughout the north of Germany, Holland, parts of France, and in our own country. From their contents the Danish antiquaries have classified them into barrows of the Stone, the Bronze, and the Iron periods—a division already suggested to English antiquaries by the contents of English barrows. Those of the Stone period are the oldest. They are often of great size, and are "peculiarly distinguished by their important circles of stones and large stone chambers, in which are found the remains of *unburnt* bodies, together with objects of stone and amber." (Worsaae, 'Primeval Antiquities of Denmark,' Thoms's Trans., p. 93.) The earth has been removed from many of the more remarkable of these barrows, so as to leave only the stone circles, chambers, or cromlechs, exposed; but enough remains, as Mr. Worsaae observes, to show that they must have been works of enormous labour; and they afford a proof that the people who formed them, and who were probably the earliest inhabitants of Denmark, however rude, "could scarcely have led a mere nomadic life, but must have had settled habitations, and that they were a vigorous people, who cherished care and reverence for the departed."

The tumuli of the Bronze period, according to the same author, "have no circles of massive stones, no stone chambers, in general no large stones on the bottom, with the exception of stone cists placed together, which, however, are easily to be distinguished from the stone chambers. They consist, as a general rule, of mere earth, with heaps of small stones, and always present themselves to the eye as mounds of earth, which, in a very few rare instances, are surrounded by a small circle of stones, and contain relics of bodies which have been burned and placed in vessels of clay with objects of metal." These tumuli belong evidently to a later period than the preceding, and to a people more advanced towards civilisation. In the rudest ages the people usually bury their dead; later, the practice of cremation is resorted to and accompanied with much religious ceremony; and it is only when the pagan rites yield before the progress of Christianity that a return is made to the simpler custom of interring the corpse unburnt. In the Scandinavian burials of the Bronze period, the body seems to have been burnt on a pile of wood; the bones and ashes were then collected, and, together with various bronze implements and ornaments belonging to the deceased, put into an earthen vessel, or rude stone chest (cist), which formed the nucleus of the intended barrow. This central vessel was surrounded with small stones, and then covered with earth, so as to form a barrow. (Worsaae.) Only persons of eminent rank or merit seem to have had an entire barrow; in most cases the barrows seem to have belonged to families, while some are evidently the ordinary burial-places of the poor, excavations being made in the barrows in order to insert urns containing bones, probably burnt at a common burning-place, as described by Mr. Kemble. The barrows of this period are usually formed on high ground, and, whenever practicable, so as to be seen far at sea. They are especially numerous in the islands, and in Jutland, Sleswig, and Holstein.

Of Danish barrows of the Iron period the examples are comparatively few, and their date is evidently comparatively recent. In external form they resemble those of the Bronze period, and they are not unlike them in their internal arrangement; but they contain only *unburnt* bodies. Swedish and Norwegian barrows occur, however, in which burnt bodies are found. A distinctive feature of the barrows of this period is that they contain "not only remains of the warrior but also those of his horse," together with his trappings. Some of them have chambers of wood, and all display traces of costly habits and comparative refinement of manners in trinkets of gold, silver, and glass, figures not inelegantly carved and engraved of birds and other animals, runic inscriptions, &c.; and in some, as indeed in some of the Bronze period, trunks of oaks, rudely hollowed out like a coffin, have been found.

The first careful investigations into the tumuli of this country were made by Dr. Stukeley in the neighbourhood of Stonehenge a century and a quarter ago. (Stukeley's 'Account of Stonehenge,' fol., 1740.) The attention of the public was a second time drawn to the subject by Douglas, in his 'Nænia Britannica,' published in 1793: his researches were confined to the southern coast of England, and chiefly to the county of Kent. The investigations begun by Stukeley and Douglas were prosecuted, with ample means to carry them into effect, by the late Sir Richard Colt Hoare, whose attention was first directed to the subject, and who was materially assisted in his researches and literary labours, by Mr. Cunnington, a tradesman and self-taught antiquary of Wiltshire. In no part of Europe had tumuli been so completely explored as by Sir R. C. Hoare in Wiltshire, and he minutely and carefully explained their contents in his 'Ancient Wiltshire,' 2 vols. fol., 1810, 1821. The classification of tumuli according to their shape, proposed by Sir R. C. Hoare, has been so generally adopted by English and French antiquaries that it may be useful to give it at length, without however accepting the conclusions which the author arrived at, and which indeed are scarcely consistent with the present state of archæology. "We must not," he observes, "consider every barrow as a mere tumulus, or mound, loosely and fortuitously thrown up, but must rather view them as works of evident design, and executed with the greatest symmetry and precision. The *Long barrow* (see No. 1, annexed illustration), from its singular form and large size, claims the first notice. These barrows differ considerably in form as well as magnitude. Some resemble the half of an egg cut down the middle; some are almost triangular; some form a ridge of equal breadth throughout; but the greater number are wider at one end than the other, and that end is usually turned towards the east. They are commonly placed on elevated situations, and stand singly. They differ materially from circular barrows in their contents; for brass weapons, or trinkets, are never found in them. With few exceptions, bodies appear to have been laid on the floor of the barrow, at the broadest end, in an irregular manner; and near one or two cists, cut in the native chalk, and covered with a pile of stones or flints. The *Bowl barrow* (No. 2) is the shape most usually found. It abounds on the Mendip Hills, in Somersetshire, and is sometimes surrounded with a shallow ditch. Dorsetshire also contains many barrows of this class. The *Bell barrow* (No. 3), from the symmetry of its shape, is probably an improvement on the bowl barrow. It occurs in the vicinity of Stonehenge.





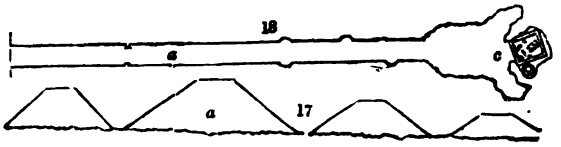
Of the *Druid barrow*, as it was miscalled by Stukeley, Sir R. C. Hoare distinguishes three varieties (Nos. 4, 10, and 11). The outward vallum, with the ditch within, is moulded with great care. In the area are sometimes one, two, or three small mounds, which in most cases have been found to contain small articles, such as cups, and lance-heads, also amber, jet, and glass beads. Two other varieties of the Druid barrow have been casually observed. One is a low mound, inclosed within a vallum, and occupying almost the whole area (No. 5). In the other, the area is perfectly flat, and rises in a curved line from the vallum (No. 9).

The *Twin barrow* (No. 7) consists of two conical mounds within a foss. The *Broad barrow* (No. 9) resembles the bowl barrow, but is wider and flatter at top. All these are regarded as belonging to the Celtic or ancient British period.

Two other forms are mentioned—the *Pond barrow* (No. 6) and the *Cone barrow* (No. 8). Of the cone barrow, only a single example has been noticed, near Everleigh, on Salisbury Plain. Small cone-shaped barrows placed together in groups are usually of Saxon date: large numbers of them occur in the eastern parts of Kent.

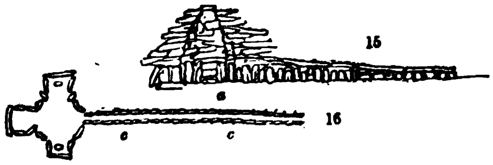
Another kind appears to have escaped the notice of Sir Richard C. Hoare. These barrows are so slightly elevated that they can scarcely be discovered, except in the morning and evening, when the shadows are broad and marked. Their contents show them to belong to an early period.

No. 12, a tumulus—or rather the ruins of a tumulus—called Mill-barrow, near Avebury, Wiltshire, set round with stones, was represented and described by Dr. Stukeley, in his work on Avebury, fol., 1743: it is fully described and figured under AVEBURY, in GEOG. DIV.



Tumuli frequently occur arranged in a row. In *fig.* 17 is shown a series of four known as the Bartlow Hills, in the county of Essex, on the south border of Cambridgeshire. They vary in size, as indicated in the diagram. The largest, *a*, measuring 142 feet in diameter by 44 feet in height, was explored in 1835 by Mr. J. G. Rokewode and other gentlemen, who excavated a passage or gallery on the surface of the natural earth, from the extreme base to near the centre of the barrow. This line or gallery is marked (No. 18) *a*, extending 56 feet, where the workmen were ordered to extend the open space on each side; and at the distance of 13 feet they came to a square inclosure, or chest (*c*), which was found to contain various antique relics of genuine Roman or of Brito-Roman manufacture. These were glass urns or bottles, a bronze lamp and cup, a patera, a præfericulum (a long or tall vase, with a particular handle), glass vessels, a folding chair, bronze strigils, an enamelled vase, &c. The last and the bronze præfericulum are elegant and extraordinary vessels, and the only examples of the kind ever found in any of the tumuli of Great Britain. A particular account of these objects is given in the 'Archæologia,' vol. xxvii.

At a place called the New Grange, near Drogheda, Ireland, there was a remarkable tumulus, which was explored in 1770 by Governor Pownall, who wrote an account of the barrow, and of other objects in the vicinity, for the Society of Antiquaries of London, and published the same in vol. ii. of the 'Archæologia.' He states that the mound consists mostly of large pebble stones, which must have been conveyed about 12 or 14 miles; and, by calculation, the whole weighed at least 189,000 lbs. The height is 70 feet, and the diameter about 400 feet. Surrounding its base was a series of rude stones, placed in a circular form, on their ends, as indicated (No. 14). A gallery formed of upright stones, *c c*, with others placed on their tops, extended from the outer edge to near the centre of the tumulus, where there was an area surrounded by other stones, and covered by a dome or cupola, *a*. Branching from this area were three square recesses, *b*, *b*, *b*. The accompanying diagrams show a plan and section of the gallery.



Silbury Hill, near Marlborough, Wiltshire, is one of the largest barrows in the world. [Avebury, in Geog. Div.] See the cut in the preceding column, No. 13.

Some very remarkable examples of tumuli, cromlechs, and stone chambers in Jersey, Guernsey, and other of the Channel Islands, have been explored and described with great acumen by Mr. Lukis. ('Archæol. Journal,' &c.) They bear, in many particulars, a curiously close affinity to the Scandinavian barrows, as described by Worsaae and the Royal Society of Antiquaries, Copenhagen. [Cromlech.]

Sir Richard C. Hoare considers the deposition of the body entire, and its reduction to ashes by fire, to have been practised in England at the same time. There are, however, varieties of both. In the most ancient interments the body is inclosed in a cist, with the legs and thighs drawn up, and the head generally turned towards the north. The second is of later date. The body is deposited at full length; but the head is placed in no particular position, and arms and various instruments of iron accompany the skeleton: these burials of unburnt bodies in English barrows bear in all respects a close similarity to those described by Mr. Kemble in North Germany. In the same manner, two modes of depositing the remains, after they were burnt, have been practised. In the more ancient, the fragments of the burnt bones were collected and laid on the floor of the barrow, or in a cist excavated in the native soil. In the second, which is clearly the later, the bones and ashes were inclosed in a funeral urn, which was placed in a cist, usually with the mouth downward. In these cases portions of the cloth which enveloped the urn have occasionally been discovered, as well as small brass pins, by which the cloth was apparently fastened.

Of urns, many varieties have been found in exploring the tumuli. The first or largest class was properly the sepulchral urn, and is always found to contain bones. The second is different both in shape and design: it contained neither ashes, bones, nor trinkets; and as the custom prevailed of depositing articles of food with the dead, these have received the name of drinking-cups, from a supposition that they were intended to hold fluids. Such vessels are frequently found with skeletons, and are placed either at their head or feet. They are always ornamented with patterns, and would contain about a quart. The third are smaller still, and more fantastic in shape. They are too diminutive to have been receptacles for ashes. They were probably intended for perfumes, and have somewhat fancifully been named incense-cups. At one time, there can be little doubt that barrows might have been found throughout the country; but they have been destroyed as cultivation advanced. Yet even now they are traceable over a large part of the land, and they exist in considerable numbers where the land remains untilled—largely, for example, in such widely-separated places as Wiltshire, Derbyshire, Kent, and the Channel Islands.

We may add that the remains found in the British barrows, equally with those of the barrows of other Teutonic races, indicate three distinct stages or eras of society. The first was before the introduction of metals, when arms and implements consisted of spear-heads of flint, and arrow-heads of flint or bone; the second, when these articles were of bronze; and the latest, when iron instruments, arms, and utensils accompany the deposit. Of the sepulchral urn also there are two varieties, indicating different periods of mechanical art. In the first the urn is fashioned by hand, without ornaments, or with those of the rudest kind, and dried by the heat of the sun. In the second, it was evidently wrought on the lathe, ornamented by the application of some instrument with zigzags and other patterns, and finished and baked with different degrees of skill and attention. Possibly the first of these may belong to the earliest known inhabitants of Britain; and the others may perhaps be assigned to the latest Belgic colonists. The later Saxons buried their dead in cemeteries of considerable extent, and without barrows.

TUN. [Ton.]

TUNE, in Music, a short air, or melody, with both or either of which terms it is synonymous. A vocal *Tune* is a song, or a ballad, in England; an *ariette*, a *vaudeville*, in France; a *gesang* in Germany; a *canzonetta*, an *arietta*, in Italy; a *seguidilla* in Spain; &c. In instrumental music a *Tune* is variously denominated,—dance, hornpipe, jig, *gigue*, *giga*; waltz, *valse*, *waltzer*, *fandango*, &c., according to the country in which it had its origin or is naturalised. [Air; Melody.]

TUNGSTEN (W). *Wolframium.* This element was discovered by Scheele in 1781, but was not isolated till some few years later. The name indicates "heavy stone," in allusion to the high specific gravity of its Swedish ore.

The chief, if not the only form in which tungsten occurs in nature, is that of tungstic acid; sometimes free, but more often combined: it is usually found in company with tin-stone, and till within the last few years has been regarded only as a mineralogical curiosity. Recently, however, tungsten has been combined with iron, and the alloy found to possess the properties of the best steel.

Tungsten may easily be obtained from tungstic acid, by reducing with hydrogen or carbon at a high temperature. The most convenient method is to knead a mixture of tungstic acid and charcoal into a paste with oil, and expose the mass in a carbon crucible to the heat of a blast furnace. It is a steel-gray metal, susceptible of considerable lustre, exceedingly hard and infusible, and of specific gravity 17·6. It does not readily oxidise in the air, and is not magnetic. It is a good conductor of heat and electricity, and by strong oxidising acids is converted into tungstic acid.

The equivalent of tungsten is 92.

Tungsten and *oxygen* form two definite compounds; *binoxide* (WO_2) and *teroxide*, or *tungstic acid* (WO_3). A dark indigo-blue coloured oxide (W_2O_5) has also been described, but it is probably a mixture, or possibly a compound of binoxide and teroxide ($W_2O_5 = WO_2, WO_3$).

Binoxide of tungsten, or *tungstous oxide* (WO_2), is a dark copper-coloured, almost black powder, obtained on passing hydrogen over tungstic acid at a low red heat. It has also been formed in lustrous scales. Binoxide of tungsten has a great tendency to absorb oxygen, but forms with soda a compound that is not acted upon by any acid, except hydrofluoric.

Tungstic acid (WO_3).—The anhydrous acid, or *tungstic anhydride*, may be procured by decomposing Wolfram (tungstate of iron and manganese $MnO, WO_3 + 3FeO, WO_3$), with aqua regia, evaporating to dryness, digesting the residue in ammonia, re-crystallising the tungstate of ammonia, drying, and heating to redness. It is a yellow powder, insoluble in water and acids, but soluble in alkalies, and in alkaline carbonates with effervescence.

Hydrated tungstic acid (HO, WO_3) is a yellow precipitate, formed on adding excess of hydrochloric acid to a solution of tungstic anhydride in alkali.

Tungstates.—Those of the alkalies are formed in the manner just indicated, and others may be obtained by double decomposition. *Tungstate of soda* ($NaO, WO_3 + 2Aq.$) possesses the important property of rendering fabrics uninflammable. Muslin soaked in a solution of 20 parts of this salt with 3 of phosphate of soda in 100 parts of water may readily be ironed and otherwise prepared for wear, and is then only charred when brought into contact with fire; it does not itself burn with flame and, therefore, does not propagate its combustion. *Tungstate of lead* rivals the carbonate as a pigment. A modification of tungstic acid in which two equivalents combine with one of base has been termed *metatungstic acid* (HO, W_2O_6).

Tungsten and *phosphorus* form two compounds. The first is a dark gray powder (W_3P_2) produced when phosphorous vapour is passed over the metal. The second (W_4P) occurs in crystalline groups of lustrous prisms, and is obtained on reducing two equivalents of phosphoric acid and one of tungstic acid in a carbon crucible at a very high temperature.

Tungsten and *sulphur* form *bisulphide* (WS_2) and *tersulphide* (WS_3). The former is a bluish-black, crystalline, plumbago-like powder, which remains undissolved when a well fused mixture of equal parts of bitungstate of potash and sulphur is treated with water. The tersulphide is produced on dissolving tungstic acid in an alkaline sulphide, and precipitating by an acid: it is slightly soluble in water, and is a powerful sulphur acid.

Tungsten and *chlorine* combine in two proportions. On passing the dry gas over the heated metal, both chlorides are formed, the relative proportions depending on the amount of chlorine. The *bichloride* (WCl_2) is less volatile than the *terchloride* (WCl_3). Both of them crystallise.

The compounds of tungsten are not poisonous. Their solutions are not precipitated by sulphide of hydrogen, or sulphide of ammonium. Sulphuric acid and zinc when added to a solution of tungstic acid produce a deep blue coloration in the liquid. With borax in the blow-pipe flame, the compounds of tungsten yield a yellow bead, becoming blood-red on cooling. The metal is estimated in the state of tungstic anhydride, which contains 79·32 per cent. of metal.

TUNGSTIC ACID. [Tungsten.]

TUNING. [Temperament and Tuning.] In column 118 we alluded to the prospectus of certain tuning-forks, of which it was stated that *each one* was tuned to the true standard by a "scientific process." We have received an explanation, by which it appears that this is the advertiser's way of saying that a good standard tuning fork having been first constructed by a scientific process, every tuning fork sold was carefully compared, by ear, with that original. This is quite as it should be; but the terms used express something different.

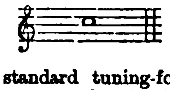
TUNING-FORK. A steel instrument with two prongs springing out of a handle, and so adjusted as to length that when struck a certain fixed note is produced, by which the pitch of the voice or of musical instruments is regulated. In England the tuning-fork is made with parallel prongs, and is vibrated by striking one of the prongs when both unite and reinforce each other; the note becomes much more resonant by placing the handle on a sounding-board, or even on a table. In France, where the instrument is called a *diapason*, and in Germany a *diaspason*, the prongs are bent into the form of an exaggerated horse shoe, and a cylinder of wood being placed in the widest part of the opening, is moved quickly upwards so as to separate the prongs further apart, and they continue to vibrate for some time. The fork is usually tuned to A or C in the tenor, a separate fork being provided for each pitch required. Mr. Klein has, however, introduced a fork which admits of adjustment for pitch by means of a small brass clamp, which slides on one of the prongs, and can be fixed in certain positions by means of a clamping screw. By varying the place of the clamp upon the prong the pitch of the fork can be raised or lowered, and certain marks are engraved upon the prong, showing the position for the clamp for giving the pitch adopted by each of the principal orchestras in Europe.

It would be very desirable if a uniform pitch could be agreed on in the musical world; but so long as each nation continues to use its own weights and measures, it will naturally claim the privilege of regulating its own musical pitch. Under Acoustics, Concert Pitch, and Temperament and Tuning, some remarks are made on this subject, by which it appears that for many years past the pitch has been rising, to the injury of the voices of our public singers. Messrs. Broadwood, the well-known pianoforte makers, employ three tuning-forks, all of different pitch: the first is the philharmonic standard of thirty years ago, and is used for tuning pianos which give the accompaniments at vocal concerts; secondly, a fork higher in pitch, used for tuning pianos that take part in orchestral compositions; and thirdly, a fork of still higher pitch, used as the opera and philharmonic standard of the present day. Indeed there is a difference of about a semitone between the first and third of these forks.

It is stated that the middle C-fork used in Paris in 1699 was equal to 489 vibrations per second, while in 1859 it had increased to 538. In the last-named year the opera standard fork used in London, St. Petersburg, and Berlin, was even somewhat higher than that of Paris; and cases have frequently occurred in which a band intended to take part with a cathedral organ, such as that of St. Paul's, London, found it impossible to tune down all their instruments to the pitch of the organ. The object of thus raising the pitch has been to improve the brilliancy of the instruments. Opera bands and military bands have both raised their pitch. The conductor of the band of the *Guides* of Brussels employs two forks, one which is too high for vocal music, being used to give brilliancy to military instruments.

Attempts have been made at various times to settle the standard of pitch by reference to scientific principles. Fischer's experiments, or rather their results, obtained in 1823, are noticed under Acoustics. About thirty years ago the Philharmonic Society adopted a fork of a certain pitch, which for a time seemed to check the tendency to rise in the standard. The maker informed us that this fork was entirely settled by ear, and that Sir George Smart directed him to make it a little sharper or a little flatter until in the course of about half an hour, a pitch was hit upon which satisfied Sir George's musical ear. In 1834 some of the leading musicians of Germany met at Stuttgard, and agreed upon an A-fork of 880 vibrations per second, corresponding with 528 for the tenor C. The next attempt to secure a uniform standard was made by Mr. Hullah, in 1842. When this gentleman introduced the system of teaching singing on the Wilhem method, under the sanction of the Committee of Council on Education, it was quite necessary to secure a common standard of pitch for the sake of uniformity in the various classes, and among the teachers instructed by Mr. Hullah, who themselves had classes in various parts of the kingdom. The great and successful gatherings in Exeter Hall, where 1500 or 2000 pupils under this method united their voices, would evidently have been impossible unless a standard of pitch had been adopted. Accordingly, Mr. Hullah and his publisher, Mr. Parker, applied to Mr. Tomlinson to prepare a new fork; the necessity for which will be further apparent when it is considered that the A-fork or the C-fork of one maker did not by any means imply the same A-fork or C-fork of another maker; nay, even forks of the same name, and bought at the same shop, were not, as a rule, in unison. Mr. Hullah expressed great anxiety that the pitch should be kept down as much as possible, but he left it to Mr. Tomlinson to decide what number of vibrations per second should be assigned to the note which it was agreed should be the middle C of the pianoforte. In a letter addressed to Mr. Hullah on April 18, 1842, Mr. Tomlinson stated his reasons why the number 512 should be adopted. We will quote a few remarks from the printed description which was written when this fork was issued, and which has been given with every fork that has been sold, ever since:—

"The tuning-forks now in use are themselves regulated—not upon any definite principle—but by the imperfect system of *copying*; each one being attuned in (apparent) unison with others. The workman, having no test but his ear to depend upon, is liable to fall into inaccuracies, the precise amount of which he has no means of determining: hence the standard itself may vary from time to time; and indeed it is known to musicians that the standard of musical pitch is higher in this country at the present time than formerly, any given note being now a little *sharper* than the similarly-named note in the times of our earlier composers. And not only so, but different vocalists of distinction, instrumental performers, and musical instrument makers, adopt certain standards of their own, which often differ considerably one from another. These discrepancies, and the rapid extension of vocal music in England under the auspices of the Committee of Council on Education, have led to the opinion that the present is a favourable time to attempt the formation of a *rigorous standard* of pitch; one which, by depending on an unchanging scientific principle, will be independent of local and temporary usages. The principle here alluded to is that on which the pitch wholly depends—namely, *the number of vibrations per second which produces the given note.* The great rapidity of these vibrations renders the determination of the number a point of much difficulty: but science furnishes many resources whereby this determination can be made with great nicety. Any note might be chosen as a standard, but the note "Do" or C, represented musically thus, has been selected as the one most generally useful:—



This note in the new standard tuning-forks, is produced by 512 vibrations per second, a number, the simplicity of which renders it peculiarly valuable. It forms part of the geometrical series, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048; each term of which thus becomes a representative of the natural note "Do" (except the first five terms, which vibrate too slowly to produce musical sounds); every term being the octave of the next below it. Under such a system the lowest C on a grand pianoforte would be due to 32 vibrations per second; the highest C to 2048, and the highest note of the instrument to 2730. By careful experiments, made expressly for the present object, it has been recently determined, that the philharmonic C, the most authoritative standard in this country, vibrates a smaller number of times per second than 512; while Fischer, of Berlin, found, a few years ago, that the average of the pitch note A, in four celebrated Continental orchestras, gave a number which would raise the C to about 516 vibrations per second. Thus the numbers of vibrations per second of the pitch-note A at the principal Berlin and Paris theatres were as follow:

	Vibrations per Sec.		Vibrations per Sec.
Berlin Theatre . . .	$437\frac{32}{100}$	which would give for the note C . .	$524\frac{78}{100}$
Paris Grand Opera Français .	$431\frac{34}{100}$	" "	$517\frac{61}{100}$
Opera Comique . . .	$427\frac{61}{100}$	" "	$513\frac{13}{100}$
Opera Italien . . .	$424\frac{17}{100}$	" "	509

"In selecting, therefore, the number 512, we not only obtain that which is theoretically most correct, but one which is also a convenient mean between various existing standards; it gives a very trifling elevation to the general English pitch, and furnishes a standard, which, for the first time in this country, can be *numerically* expressed in connection with the tuning-fork."

It is further stated that "every fork is tested by an uniform standard, and stamped with a device expressive of the velocity of its vibrations = 512 per second."

It is remarkable that this fork should have been almost entirely confined to the use of Professor Hullah's singing-classes, and that when the Society of Arts committee was appointed the existence of a standard for nearly twenty years, of which many thousands had been issued to the public, should have been known only to a few of the members of that committee. This committee seems to have been appointed in consequence of the imperial government of France having in 1858 appointed a commission to inquire into the best mode of settling a *diapason normal.* The commissioners, among whom were some eminent composers, as well as men of science, presented their report early in 1859, in which it was admitted that the standard of pitch differs in different countries; that it differs among different musical establishments in the same country; that there is a tendency everywhere to an elevation in pitch; and that great confusion arises from these circumstances. It was agreed that the Paris Opera standard ought to be lowered; and in order that existing musical instruments might be readily adapted to a lower pitch, about half a semitone of diminution was recommended: namely, that the Opera A fork should be lowered from 896 to 870 vibrations per second, equivalent to a lowering of the tenor C from 538 to 522. A decree of the Emperor sanctioned this standard, and made it compulsory on all musical establishments in any way supported by the state to adopt this standard at Paris from the 1st of July, 1859, and in the provinces from the 1st of December following.

The preliminary meeting of the Society of Arts was held on the 3rd of June, 1859. A large number of musical gentlemen and one lady, Madame Goldschmidt (Jenny Lind), attended, together with a few scientific men. It was agreed that the pitch had gradually risen, was still rising, that it ought to be checked, and that the settlement of a definite standard, once for all, was very desirable. Madame Goldschmidt stated that within the short space of twelve years the pitch had risen sufficiently to make the change painful to the singers of soprano music. A committee was appointed to examine and report on the question: the deliberations lasted twelve months. It is worthy of remark that Sir John Herschel addressed a letter to the committee, in which he expressed his astonishment that the French commission should have fixed upon the number 870 for their A fork, or 522 for C; and he expressed his conviction that sooner or later the mathematically simple and easily calculated 512 must be adopted. His proposal was to re-form the pitch effectually, and once for all, by the adoption of that number. The instrument-makers, he remarks, would be somewhat puzzled by *any* change, but that the embarrassment would not be increased by making the full required alteration at once. The committee, however, reported in favour of a number between the two extremes—namely, 528, or the pitch established by the Stuttgard musicians in 1834. The instrumental performers stated to the committee that they could lower the Opera pitch of 546 down to 528, but if they had to lower it to 512 some of them would have to purchase new instruments. On the other hand, the vocalists who would have preferred 512 were content to accept 528 as a compromise in the right direction. Besides this, 528 was recommended as a good number for the fundamental note of the octave, since it admits of the other notes of the scale being expressed in whole numbers without fractions. At the presentation of the report a strong attempt was made to obtain a vote in favour of 512, but without success; so that for some time to come this number will probably only reign in Professor Hullah's singing-classes.

The scientific process by which the number of vibrations per second is determined, consists in the use of one of three or four methods. The first is by means of the monochord, a string of known length and diameter, stretched by a known weight usually in a horizontal position. The length of the string is the vibrating portion between two well-defined edges or bridges, and the weight is guided over a very small pulley. Fischer was, we believe, the first to point out a source of error in this arrangement, namely, that in the horizontal position the string is prevented by friction from experiencing the full effect of the weight, and the calculation will give the number of vibrations in excess of the true value. The string must therefore be in a vertical position. The formula convenient for calculation results from the mathematical theory of the vibrations of a stretched cord:—

Let l = the length *in inches* of the cord or wire.
c = the length *also in inches*, whose weight would be equal to that by which it is stretched.

Then the number of vibrations per second will be

$$N=\frac{\sqrt{c}}{l}\times 9{\cdot}8257,$$

in which 9·8257 is $\frac{1}{2}\sqrt{g}$, g being the accelerative force of the gravity of the earth at its surface, expressed in inches.

Mr. Woolhouse ('Essay on Musical Intervals') took a piece of the stoutest plain string of the pianoforte, weighing very nearly 2 grains to the inch: 272 inches weighed just 9 drams or 540 grains. A length of 7·28 inches, stretched in a vertical position by a weight of 28 lbs. avoir., sounded the common pitch-note A: hence, according to the preceding formula, $c = 98726$ inches; $\sqrt{c} = 314{\cdot}2$ inches; $\sqrt{c} \times 9{\cdot}8257 = 3087{\cdot}2$ inches; and $N=\frac{3087{\cdot}2}{7{\cdot}28}=424$. "We therefore conclude that the pitch-note A vibrates about 424 times in one second. This may differ one or two vibrations from the truth, on account of the unavoidable small defects of the materials used in the experiment." According to this determination the notes of the octave have the following values:—C 254, D 286, E 318, F 339, G 382, A 424, B 477, and C 509 vibrations per second respectively.

The second mode of determining the pitch of a given note is by means of the SYREN, and the method of doing so is briefly, but perhaps sufficiently, described under that head. For the method of BEATS, we may refer to that head, and likewise to the articles ACOUSTICS, and TEMPERAMENT and TUNING. But the most rapid and striking method of determining the number of vibrations in a given note is that recently introduced by M. Lissajoux [NODAL POINTS AND LINES]. By means of an electro-magnetic machine a disc one metre in circumference moves with strict uniformity, and makes one revolution in one second. This disc is covered with a thin layer of copperplate printer's ink, and the fork is furnished with a small ivory point. On vibrating the fork and bringing the point up to the rotating disc, it will engrave a number of tooth-like waves, which have only to be counted in order to determine the number of vibrations per second of the fork.

The law which regulates the vibrations of a tongue of metal fixed at one extremity, and free to vibrate at the other, is that the number of vibrations of similar tongues, but of different lengths, are in the inverse ratio of the squares of those lengths. Thus if one tongue be twice as long as the other, the shorter will perform four times as many vibrations in a given time as the longer. The method of tuning a fork by a standard is to sound the fork with that standard, and if it agrees with it, the two notes will sound in unison as one; if it do not agree, a system of beats will be heard more or less rapid according to the divergence. The tuner then adopts one of two methods: by means of a flat file he rubs off a portion from the ends of the prongs, thus reducing them in length, and making them vibrate quicker; or he introduces a rat's tail file and removes a portion from between the prongs, thus increasing their effective length and causing them to vibrate slower.

It is undoubtedly true, that the pitch even of the tuning-fork is liable to slight variations from change of temperature. While writing this article we have performed the following experiment: two forks were sounded together and found to be strictly in unison; one of them was plunged into hot water for a few seconds, then wiped dry, and again sounded with the other fork, when a very painful beat was evident.

On striking a tuning-fork briskly on a hard substance, other notes besides the fundamental note may sometimes be heard. This arises from nodal divisions in each limb, after the manner of strings and tubes [PIPE], but not following quite the same laws. Where there is one node it is at a distance from the fixed point, a little greater than two-thirds the length of the prong; the note then given by this, which is called the second mode, is much sharper than when there is no node (or by the first mode), and the relative number of vibrations is $\frac{25}{4}$. A still higher note corresponds to two nodes (third mode), and one still higher to three nodes (fourth mode). These subdivisions of vibrating rods may also be produced in tubes. The squares of the odd numbers 3, 5, 7, 9, &c., represent with sufficient exactness the relations of the number of vibrations corresponding to the second mode, third mode, fourth mode, &c. Under all these circumstances it may be stated:—1. That the number of vibrations of similar springs of different lengths is in the inverse ratio of the squares of the lengths; 2. That the number of vibrations of springs of the same length, but of different thicknesses, is proportional to their thicknesses; 3. That the width of a spring has no influence on the number of its vibrations, provided it be small with respect to its length, and that it vibrates after the first mode; 4. That springs of equal size, but of different material, such as wood, glass, steel, &c., do not give the same note, because the number of the vibrations depends upon the density and rigidity of matter.

A tuning-fork may be made to furnish several beautiful illustrations of interference. [INTERFERENCE.] If a vibrating tuning-fork be held to the ear and turned gradually round, the sound will increase and diminish in a remarkable manner; when the prongs are presented at an angle of 45° the sound is scarcely if at all perceptible. In such cases, when the prongs coincide, or are equally distant from the ear, the waves of sound combine their effects, whilst in intermediate positions they reach the ear in different phases, and interfere and produce total or partial silence. A similar effect is produced by fixing the fork to the mandril of a lathe, the length of the fork coinciding with the axis of motion; if the fork be vibrated no sound will be heard while it is rotating. If a vibrating tuning-fork be held with its handle obliquely in contact with the table, the resonance of the table is heard while the fork is at rest; but if the fork be moved parallel to itself along the surface of the table, the resonance ceases, from the interference of the planes of vibration with each other. The moment the handle is brought to rest, the resonance is again heard. If the tuning-fork be held vertically, the resonance is not interrupted by moving it about, since the planes of vibration coincide. If a vibrating tuning-fork be held over a cylindrical glass vessel of suitable length, the air in the glass will be made to vibrate and produce a tone. If a second glass cylinder be held at right angles to the first, so that the respective openings of the two vessels form a right angle, the musical tone previously heard will cease, but will sound again on removing the second vessel, an effect which arises from the interference of the vibrations of the air in the two vessels.

TUNNEL, in civil engineering, an arched passage formed underground to conduct a canal or road on a lower level than the natural surface. The derivation of this word, which, in the sense above given, is unnoticed by most lexicographers, is rather uncertain. Richardson places it among the derivatives of *tun*, and defines it as "any inclosure, inclosed way or passage;" as a chimney-tunnel, or passage for smoke, in which sense the word *tunnel* or *tonnell* is used by Spenser and other early English writers; a passage for liquor, in which sense, as well as in that last mentioned, it is convertible with *funnel;* or a net shaped like a tunnel for liquids, wide at the mouth, and diminishing to a point. He also observes that "Tooke thinks *tun* and its diminutive *tunnel* (Anglo-Saxon, *Tunel, tenel*) are the past participles of the [Anglo-Saxon] verb *tyn-an*, to enclose, to encompass."

Long tunnels are usually made through hills in order to avoid the inconvenience and loss of power occasioned by conducting a canal, road, or railway over elevated ground, and the enormous expense of such an open excavation as would be necessary in order to preserve the requisite level. Those of less extent are frequently constructed to avoid the opposition of landowners, or to afford uninterrupted passage under a road, canal, or river. Many tunnels of the latter character differ in no material point from bridges; but in the case of oblique crossings a tunnel is distinguished from an oblique or skew bridge by its faces being at right angles with the direction of the lower passage, instead of being parallel with the direction of the upper passage. Of this character are the tunnels under the Hampstead Road, between Euston Square and Camden Town, and the Kensall Green tunnel, under the Harrow Road, both on the line of the London and North-Western railway; and on the West London railway, passing under the Paddington canal at Wormholt Scrubbs. The Thames tunnel is the most remarkable example of tunnelling under a river, and, although far less extensive than many other tunnels, it is, from the almost insuperable difficulties of its situation, perhaps the most astonishing work of the kind ever executed. Another class of tunnels are those made under towns, in order to form a canal or railway communication with points which are inaccessible by an open passage, except at great expense. The Regent's canal, for example, passes under Islington, London, by a tunnel three-quarters of a mile long; and the Liverpool and Manchester railway is conducted from the station at Edge Hill, on the outskirts of Liverpool, to the docks at Wapping, for goods traffic, and to Lime Street, in the centre of the town, for passenger traffic, by two tunnels, each of which is about a mile and a quarter long.

The construction of tunnels is by no means of recent origin, although it is only of late that they have become common. The outlet for the drainage of the lake Copaïs in Bœotia [Bœotia, in Geog. Div.] is one of the oldest monuments of the labour of man. The great tunnel in Samos, which was seven stadia, or 4200 Greek feet, in length, was driven through a mountain 900 feet high, for the purpose of serving as the bed of a channel to convey water from a natural source to the city of Samos. (Herod., iii. 60.) The Posilipo near Naples, which is at least as old as the beginning of the reign of Tiberius, is a tunnel three-quarters of a mile long. The tunnel which was made at an early period in the Roman republic for the partial drainage of the Alban Lake is above a mile in length. Of ancient works of this character there is a remarkable example in the subterranean canal from lake Fucinus, or the lake of Celano, to the river Siris, originally formed by the emperor Claudius, and cleared out some years since by order of the Neapolitan government. This extensive tunnel, which is about three miles long, thirty feet high and twenty-eight wide at the entrance, and nowhere less than twenty feet high, passes in part through solid rock, and is lined in other places with masonry; and it appears to have been constructed in a manner resembling that now usually followed, the excavation having been carried on by several parties or gangs simultaneously, by means of vertical shafts, and inclined passages or galleries from the sides of the mountain. A minute account of the tunnel, as it appeared during the clearing-out, is given in the thirty-eighth volume of 'Blackwood's Edinburgh Magazine' (p. 657), in a paper entitled 'Eight Days in the Abruzzi.' The object of this tunnel is to carry off the superfluous waters of the lake; but in more recent times similar works have been executed for navigable canals. These are generally in England of small transverse dimensions, being calculated for the passage of single boats, and very often without towing-paths, in which case the boats are either hauled through by a rope or chain, worked by a steam-engine, or propelled by men lying on their backs on the deck, or on projecting boards provided for the purpose, and thrusting against the sides or roof of the tunnel with their feet. This dangerous practice has occasioned much loss of life, and is also objectionable on account of its tediousness, as boats are often detained for a long time at one end of the tunnel while a boat is coming from the opposite end. In the evidence before the House of Lords on the Great Western Railway bill, in 1835, it was stated that great delays were experienced at the Islington tunnel when any accidental derangement prevented the steam-engine and chain from working; because, although boats were occasionally "legged" through in as little as seventeen minutes, the ordinary time required for working a light barge through the tunnel, by two men, was half an hour, and for a loaded barge three-quarters of an hour, or frequently an hour. In such cases boats arriving in the opposite direction had to wait at the mouth of the tunnel, until, frequently, as many as half a dozen were collected, which, when their turn arrived, passed through in a train. At some of the longer tunnels this inconvenience was even greater. At the Harecastle tunnel, on the Trent and Mersey, or Grand Trunk canal, two hours were formerly required to effect a passage of little more than a mile and a half. "This place is so frequented," observes the Baron Dupin, in his 'Commercial Power of Great Britain,' "that at the moment when the passage begins, a file of boats a mile long is often seen." To prevent confusion, those going towards Liverpool were allowed to pass in the morning only, and those in the contrary direction in the evening. This tunnel, which was formed by Brindley, and was one of the earliest works of the kind executed in this country, was commenced about the year 1766. It is 2880 yards long, 12 feet wide, and 9 feet high, and is in some parts as much as 70 yards beneath the surface. It is lined with a semicircular brick arch, and was completed for the small sum of 3*l.* 10*s.* 8*d.* per yard. Increased traffic upon the canal having rendered it necessary either to construct a new tunnel or to enlarge the old one, the former alternative was adopted; and in 1822 Telford was engaged to superintend the work. The new tunnel, which runs parallel with that of Brindley, is 2926 yards long, 14 feet wide, and 16 feet high; and, notwithstanding its greater dimensions, it was executed in less than three years: the original tunnel occupied eleven years. The new tunnel has an iron towing-path, so supported as to allow the water to play freely beneath it, which gives the advantage, so far as the play of the waves is concerned, of a waterway of the full width of the tunnel. It is perfectly straight, and the light can be seen from end to end; and so agreeable is the travelling through it, that one of the bargemen said, after passing it, that he wished it extended all the way to Manchester.

Although in some cases the adoption of a tunnel on a line of railway or canal may be decided by the necessity of non-interference with property on the surface, it is more generally a question of expediency, which involves the consideration of many important points, among which the nature of the ground is one of the first. The ground should be examined by numerous borings, because sudden breaks or faults in the strata, which may occasion great difficulty and expense in tunnelling, may otherwise escape notice. The Kilsby tunnel, on the London and North-Western Railway, presents a case in point; the trial shafts having been accidentally sunk just beyond the limits of a bed of sand and gravel, so full of water as to resemble a quicksand, occasioned so much difficulty that the contractors had to relinquish the work, which had been let for 99,000*l.*, but ultimately cost upwards of 320,000*l.*, or about 133*l.* per yard. If the first small borings appear satisfactory, shafts of at least four feet diameter should be sunk along the line of the tunnel, down to its extreme depth; and the quantity of water which appears in these shafts in a given time be noted, in order to ascertain, as nearly as possible, what draining power is requisite. If the trial shafts be judiciously placed, they may subsequently be used as working shafts, which will render the expense of forming them of large diameter immaterial. When the quantity of water and the nature of the strata have been thus tested, the engineer possesses data for calculating the comparative cost of a tunnel and an open cutting, in doing which it is necessary to consider the adjoining works of the line. If embankments be required within a reasonable distance of the proposed tunnel, it may become a question whether it will be more economical to make a cutting, and to carry the excavated earth to the embankment, or to adopt a tunnel, and to obtain the required quantity of earth for the embankment from side-cutting, or in any other way. Sometimes it may be necessary to deposit the material taken out of the tunnel in spoil-banks, in which case the power of obtaining sites for them, and of making convenient temporary roads or tramways for the removal of the earth, must be considered in selecting the positions for the working shafts. These are only a few of the points to be considered in estimating the expense of a tunnel, among the less prominent of which is the probability of being called upon for damages owing to the intersection of springs, which may occasion mischief at a great distance. Cases have occurred in which the water has been drawn from wells a mile from the tunnel. This evil may often be remedied by sinking the wells to a greater depth, but in some cases it is better to offer compensation at once. The cost of the actual making of the tunnel varies very greatly, according to the nature of the ground and the amount of brickwork required. Lecount, in the article 'Tunnel' in the 'Encyclopædia Britannica,' states that many of the old canal tunnels were made for less than 4*l.* per lineal yard, and that railway tunnels of the ordinary dimensions vary from about 20*l.* per yard, in sandstone rock, which is at once easy to excavate, and able to stand without any lining of brickwork or masonry, up to from 100*l.* to 140*l.* per yard in very loose bad ground, such as a quicksand, which may require a lining of brickwork twenty-seven inches thick. The cost of the Thames tunnel was about 1200*l.* per yard; but in this case, in addition to the unparalleled difficulties attending the excavation, the amount of brickwork is much greater than in ordinary tunnels, and there are two arches, each of which may be considered a distinct tunnel.

Rocky strata, if the stone be of a nature to work freely, are usually the cheapest for tunnelling, owing to the absence of lining, and the power of saving labour by the use of gunpowder. In the extraordinary tunnels and rock excavations at Bishopton, on the Glasgow, Paisley, and Greenock railway, 314 tons of gunpowder were used in a length of 2300 yards in hard whinstone, some veins of which were so hard that the rate of progress at each face of the excavation varied from three feet six inches to six inches only per diem. The Box tunnel, on the Great Western railway, passes for a considerable distance through strata of Bath freestone, geologically termed the great oolite formation, and presents some features worthy of notice. Major-General Pasley was deputed by the Board of Trade to examine this tunnel, and from his report, dated August 12, 1842, the following particulars are derived:—"The tunnel occurs on a gradient or inclination of 1 in 100, ascending from west to east, while the natural dip of the oolitic strata is about the same in the opposite direction: they are nearly horizontal in a direction from north to south, or transverse to that of the tunnel. The strata vary in thickness from 2½ to 4 feet and upwards, and are intersected by vertical fissures, of trifling width, but of considerable height; the direction of which is generally at right angles with that of the tunnel, but in some cases obliquely across it." The eastern end of the tunnel is, for a short distance, lined with masonry; beyond which, for about half a mile, the excavation is left without any support from masonry or brickwork, its extreme width being, in this part, 30 feet, and its height varying from 30 to 40 feet, in order to avoid finishing above in any stratum of doubtful character, which, though sufficiently strong in the sides, might not be so trustworthy as a roof. The sides of the excavation are cut in the form of an oblong elliptical or nearly a Gothic arch; but the uppermost bed of oolite, which forms the roof of the tunnel, has not been completed in that form, but has, for greater strength, been left flat for a width of two or three feet; and in order to avoid the risk of exfoliation which would have attended the cutting of the edges of the strata to a thin wedge shape, had the curved line of the tunnel been continued unbroken where it intersects them in the sides of the roof, they are cut in the form of steps, each stratum presenting a thick blunt edge; so that, in the words of Pasley's report, "the upper strata of the oolite being supported by those below them, beyond which they each successively project in a moderate degree, like corbels in architecture, the whole enter into that sort of combination which has the strength of an arch without its form; provided that the vertical fissures do not cut through them longitudinally," of which no symptom was apparent. The remaining portion of the Box tunnel, passing in the centre through beds of fullers'-earth and clay below the great oolite formation, and towards the western extremity through the inferior oolite, is arched over with brickwork, varying in thickness from four to seven concentric half-brick rings, and at the western entrance containing nine such rings. An inverted arch is introduced excepting where the oolite forms the foundation or bottom of the tunnel; and in some parts a portion of the side walls has been formed of the inferior oolite, unprotected by brickwork, although it has not in any instance been trusted for the roof. The judicious adoption of such changes in the amount of masonry forms an important part of the duty of the engineer, and is essential to the construction of tunnels at a moderate expense, although it may occasionally lead to failure, as in the case of the Summit tunnel at Littleborough, on the Manchester and Leeds railway, where, in passing through a stratum of blue shale, the invert had been discontinued for a short distance; but the shale, although apparently hard and firm, was so affected by the atmosphere as to soften and yield under the pressure of the sides, rendering it necessary subsequently to put in a strong invert of masonry.

Tunnelling in clay is frequently attended with formidable difficulties which render it very expensive. It is, when tough, a difficult material to remove, blasting being of no use, and spades and pickaxes being almost inapplicable. Lecount states that in such cases hatchets may be used to advantage, but that cross-cut saws answer best. The Primrose Hill tunnel, on the London and North-Western railway, passing through the London clay, is an example of the difficulties of such a material. The engineers, warned by the failure of the tunnel attempted some years before through the same material at Highgate, on what is now called the Archway road, which fell in owing to the insufficiency of the brick lining, adopted unusual precautions in the first instance, excavating only nine feet in advance of the brickwork, and supporting the clay by very strong timbering until the arching was complete. Owing however to the extraordinary mobility of the moist clay, the pressure upon the brickwork was so great as to squeeze the mortar from the joints, and to bring the inner edges of the bricks in contact. The evil was augmented by the form of the bricks, which, according to the custom in and near London, were made with hollow surfaces, and were consequently unfit to bear great pressure, because their edges only could come in contact. The result was, as stated in Lecount's 'History of the Railway, connecting London and Birmingham,' pp. 32, 33, that "by degrees the bricks were grinding to dust, and the dimensions of the tunnel insensibly, but irresistibly, contracting." This difficulty was overcome by the use of very hard bricks laid in Roman cement, which, by setting hard before the external pressure became so great as to force the bricks into actual contact, enabled the whole surface of the brick, instead of its edges only, to resist the pressure. The thickness of the brickwork was also increased, so that in most parts of the tunnel it amounts to twenty-seven inches. The occurrence of a similar material in the line of the Fareham tunnel, on the Gosport branch railway, occasioned great expense, and produced a slip of the superincumbent earth which carried away about forty yards in length of the brick arching, although it was of the unusual thickness of three feet.

Tunnels formed through chalk are often impeded by faults or cavities filled with wet gravel or sand, which pour a flood of semifluid matter into the excavation as soon as they are cut into. The irruption of such loose materials, as well as of water alone, has in many cases occasioned difficulties almost insurmountable. In the Watford tunnel, on the London and North-Western railway, which passes through the upper chalk formation, where it is covered with a thick irregular bed of gravel, such breaks occasioned great inconvenience. The chalk had occasional fissures, sometimes as much as one hundred feet deep, filled with clean gravel, "which," observes Lecount ('History,' &c., p. 114), "when worked into, rushed down with such violence, as to plough the walls of the tunnel as if bullets had been shot against it." Such an accident, occurring at the foot of one of the working shafts, overwhelmed ten men who were at work in the tunnel, and led to the construction of the large ventilating shaft near the centre of the tunnel, which occupies the site of the cavity. Loose sand is perhaps the most difficult soil that can be met with in tunnelling, but it has been in several instances successfully passed through. In the tunnel on the Leicester and Swannington railway, one of the earliest railway tunnels, a loose dry running sand was encountered for a distance of five hundred yards, in which it was necessary to make a wooden tunnel to support the soil while the brickwork was executed. When water occurs with the loose soil the difficulty is still greater. This was the case in part of the Wapping tunnel at Liverpool, a portion of which fell in, to a depth of thirty feet from the surface. The Kilsby tunnel, before alluded to, is a more striking example of this kind of difficulty. Mr. Stephenson, the engineer, conquered this obstacle by sinking shafts, a little beside the line of the tunnel, for pumping out the water, and so draining the sand until it was sufficiently dry for tunnelling. These shafts were sunk through the quicksand by means of wooden tubbing, and from them headings were driven to collect the water and to conduct it to the pumps. Steam-engines were erected to work the pumps, which were used incessantly for nine months before the sand was dry enough to allow the work to proceed: during a great part of that time two thousand gallons of water were removed per minute. When the working of the tunnel was recommenced, headings were driven from the pumping shafts to the bottom of the working shafts, by means of which the tunnel was freed from water. The quicksand extends over about four hundred and fifty yards of the length of the tunnel, and its bottom dips to about six feet below the arch. On the occasion of an irruption of water in another part of the tunnel, in which it was desirable to complete the arching of a portion already executed before it was possible to get rid of the water, that object was effected by floating the men and materials to the spot upon a raft. Water has been met with in large quantities in several other tunnels. It flowed so freely from fissures in the freestone rock through which the Box tunnel is driven, that in November, 1837, the steam-engine employed in pumping proved insufficient, and the water filled one division of the tunnel, and rose to the height of fifty-six feet in the shaft, thereby suspending the work until the following July, when the water was overcome by means of a second engine, of fifty-horse power. After another irruption in the same tunnel, the water was pumped out at the rate of thirty-two thousand hogsheads a day. The progress of the Merstham and several other tunnels was stopped for a time in like manner. In no case however has the irruption of water or the badness of the ground proved so serious a difficulty as in the Thames tunnel.

Short tunnels are occasionally excavated from the ends only, but those of considerable length are usually formed by sinking vertical shafts, about nine feet in diameter, down to the level of the tunnel, and excavating in each direction from the bottom of those shafts, until the several parties of workmen meet in the intermediate portions. By this means the work can proceed at any required number of points or faces, so as to bring the execution of the tunnel, whatever may be its length, within a moderate period of time. The accurate junction of these detached workings is provided for in the following manner:—In setting out the tunnel, the engineer plants a transit-instrument in an observatory erected in the line of the tunnel, supporting it on a pier insulated from the building to prevent vibration. If a road happen to pass near the observatory, the ground should be excavated round the pier to a depth of from six to ten feet, according to the traffic, for the same purpose. A distant mark should then be selected in the line of the tunnel, and a fixed point placed as an adjusting spot for the line of direction, which point should be at a considerable distance. Intermediate marks for the working and ventilating shafts may then be set out correctly; and as these shafts are sunk, the points determined by the transit-instrument are carried downwards by carefully suspended plummets, which should be of iron, and let down in buckets of water, or, which is better, in cups of mercury, to check vibration. When the shafts are cleared out at the bottom, other transit-instruments may be placed in them, the plumb-line and transit being kept as far apart as possible. The intersection of the vertical hairs in the transit with the plumb-line will then enable the engineer properly to set out the work. By these means junctions are effected between the several workings, or *shifts*, with surprising accuracy. In a length of 1520 feet between two shafts of the Box tunnel, which has a slope of 1 in 100, the junction of the two shifts was perfect in point of level, and did not deviate more than an inch and a quarter in any place at the sides. Even in curved tunnels, although the difficulty is increased, great exactness is attainable. In those on the Glasgow and Greenock railway at Bishopton, the deviation from perfect correctness nowhere exceeded two inches.

The number of working shafts in a given length of tunnel is determined by the nature of the ground and the time allowed for excavation. They should be so near together as to allow the tunnel to be excavated and lined, if brickwork be requisite, for a length equal to one-half of the distance between two shafts, at least two months before the time appointed for the completion of the tunnel; that time being desirable to allow for accidents, for building the tunnel-fronts, ballasting and laying the railway, &c. The shafts are usually 9 feet in diameter in the clear, and lined with brickwork 9 inches thick, laid in cement; all the bricks being laid as *headers*, or with their ends towards the centre of the shaft; but the substance of the brickwork must vary with circumstances, and engineers are by no means uniform as to the dimensions of their shafts. Those of the Box tunnel are mostly 25 feet in diameter, while some tunnels have been excavated with shafts of only 3 or 4 feet. Down to a depth of 50 or 60 feet the earth may be removed by means of a simple roller or winch worked by two men; and when the depth is greater a horse-gin may be erected to draw up the loaded skips or buckets. The depth at which the horse-gin becomes preferable is however dependent in some degree upon the nature of the strata to be excavated; because when they are hard, the men above may have to wait occasionally for the coming up of the skip; and it is better to have only two men at a stand-still instead of a horse, a horse-boy, and a banksman or skip lander. The roll or winch is, at the commencement of the shaft, supported by four bars or cills laid across each other on the ground; and the excavation is continued until the earth exhibits signs of weakness. A wooden curb or ring about 3 inches thick, and as wide as the brick lining is to be, is then laid in, and upon this the brickwork is laid. When the lining of this portion of the shaft, which is frequently but half a brick, or 4½ inches in thickness, is completed, the excavation is recommenced, and is carried down in a vertical line even with the inner surface of the brickwork, which is then supported by the earth left under the curb, which may be further supported if necessary by diagonal timber props. When the excavation has been carried so much deeper that the ground again appears weak, a second curb is inserted in a groove cut in the earth, and the ground between the two curbs is divided into four, six, or eight vertical masses, of which one or two are removed to a depth equal to the thickness of the brickwork. The wall is then built up in its place, and a further portion of earth is removed, and so on until the lining is complete. When the shaft is carried down to the full depth, the miners begin to excavate laterally by forming a heading or driftway along the level of the upper part of the tunnel. Sometimes such a drift is formed throughout the whole length of the tunnel before any part is opened out to the full size; but in other cases it is made in short portions, little exceeding the lengths in which the excavation of the tunnel itself is carried on, which may vary, according to the ground, from 3 to 15 feet. In the former case the driftway, which is about 4 feet wide and 5 feet high, affords a satisfactory test of the strata to be passed through, and of the probable quantity of water to be met with, for which it may in some cases serve as an adit or drain; and for these reasons such a heading is occasionally formed before letting the contracts for the tunnelling.

In addition to the working shafts, the contractor is usually allowed to sink any number of small air-shafts of 3 or 4 feet diameter, as may be necessary to prevent the accumulation of foul air in the workings of the tunnel; provided that no such shaft shall open into a public road, or be within 50 feet of a working shaft. These are formed in a similar manner to the working shafts, and both are finished at their lower ends by resting upon a cast-iron curb or ring imbedded in the masonry of the roof of the tunnel, and at the upper ends, after the works are completed, by building them about 10 feet above the surface, and coping them with stone. In very long tunnels one or more large permanent shafts are desirable for the purpose of ventilation, and also to admit light, so as in some degree to lessen their gloom. In the Kilsby tunnel, which is between a mile and a quarter and a mile and a half long, there are two such ventilating shafts, 60 feet in diameter and about 100 and 132 feet deep respectively. These were built from the top downwards, in the manner above described, in portions 10 feet deep, and from 6 to 12 feet wide. Lecount gives the following directions for the brickwork of such a shaft, if made in unfavourable ground:—The tunnel itself at the point of intersection should be of stone. The lower part of the shaft, to the height of 46 feet, should be 3 feet thick; the next 17 feet, 2 feet 8 inches thick; the next portion of the like extent, 2 feet 3 inches; and the uppermost 16 feet, 1 foot 10 inches. The bricks should be laid in alternate courses of headers and stretchers, and each brick should be well flushed up. The top may be finished with a stone coping and an iron railing, and protected by an iron fence wall, to prevent the risk of anything being thrown down the shaft either by accident or design. In some tunnels a large oblong excavation, called an *eye*, is introduced in lieu of a circular ventilating shaft. In the Bishopton tunnel there is such an eye 300 feet long; and there are two similar openings in the Glasgow tunnel of the Edinburgh and Glasgow railway.

After the completion of the driftway, either through the tunnel or to the length of a single stage only, the miners excavate the tunnel to its full dimensions, beginning by cutting downwards, and propping up the earth with timbers as they proceed; those which support the roof being at such an elevation as to allow the centering to be set up and the brick arch to be built beneath them. The bars which immediately support the earth, extending from the top or outside of the completed brickwork to a framework placed against the face of the excavation, are called *side bars*, and are in favourable earth required at the upper part of the tunnel only; but in bad ground they are required sometimes as low as the springing of the inverted arch which forms the bottom of the tunnel. When a complete brick lining is required, the invert is the part first built, and it is completed by a course of stone laid along each side, at the point where the side walls spring from it. These courses of stone, which are marked *a, a, a, a,* in the subjoined cuts, *figs.* 1 and 2, consist of blocks about three feet long, well bedded in mortar, upon a few courses of brickwork laid as a footing. The side walls are next raised, with such a batter or curvature as may enable them best to sustain the pressure of the external earth; and when they are raised to the level of the springing of the arch, beams of wood, called *cills*, are laid across the tunnel and built in with the brickwork. Upon these cills the trusses of the centering are set up, and adjusted with wedges to the proper height. Laggins, or pieces of wood stretching longitudinally from one centering to another, are then added, and upon these the bricks are laid. In some cases the cills are supported upon trestles, instead of being built into the walls; and where this is not the case, the holes left in the masonry must, after the removal of the cills, be carefully filled up. The excavation should always be made as nearly as possible of the size and shape of the intended masonry; and as the building proceeds, every cavity left outside the brickwork should be carefully filled up. Well-pounded clay may for this purpose be rammed under the invert, and almost any other material may be used for the sides and roof. The ramming of the sides may be performed after the laying of every second course of brickwork, and that above the arch as frequently as convenient. The timbers used to support the superincumbent earth are in most cases removed as soon as the arch is completed; but in very bad ground it is sometimes necessary to leave them imbedded in the earth. When the work has proceeded so far that the excavations from the two adjoining shafts are within about fifty yards of each other, if no driftway have been previously made through the tunnel, it is advisable to drive a heading through the intervening earth, to insure a perfect junction of the two shifts.

Fig. 1.

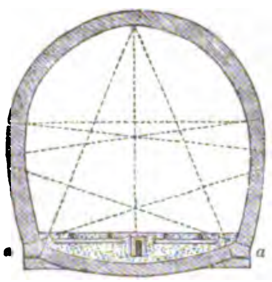
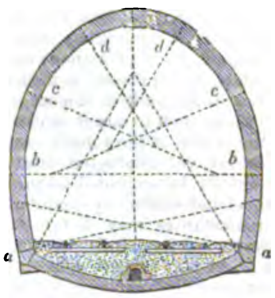


Fig. 2.



Many of the earlier tunnels were constructed with vertical sides and a semicircular arch; but it is now more usual to have the sides curved or battered, the degree of curvature, as well as the shape of the arch which forms the roof, being varied according to the nature of the ground, as soft semi-fluid ground will press much more equally in every direction than strata of a harder and drier character, and will therefore require a nearer approach to the circular form. The annexed cuts represent two varieties of form, the details of which are taken from the first series of Brees's 'Railway Practice.' *Fig.* 1 is the form of the Primrose Hill tunnel, in movable London clay. The invert, which consists of three concentric half-brick rings, is a curve of 25 feet radius; the arch, of four half-brick rings,* is struck with a radius of 11 feet 9 inches; and the sides are arcs of 27 feet 6 inches radius. The width of the tunnel is 21 feet 5 inches at the springing of the invert, and 24 feet 8 inches at the widest part. The clear height of the tunnel is 21 feet 8 inches, the remaining depth of 3 feet 4 inches being occupied by the ballasting, drain, &c. The side walls are 18 inches thick, like the arch which constitutes the roof. *Fig.* 2, which represents the transverse section of the Linsdale and Kilsby tunnels, both on the North-Western railway, has an elliptical arch, consisting of several circular arcs, of which the lower pair, extending from the invert to the point marked *b*, are struck from radii of 42 feet 8 inches, the centres being upon an horizontal line 8 feet 4 inches above the springing of the invert; the portion from *b* to *c* has radii of 21 feet, the centres being on the same horizontal line; that from *c* to *d* has radii of 14 feet 4¼ inches; and the crown of the arch is a curve of 9 feet radius. In this case also the invert, instead of being struck from a centre in the crown of the arch, has its centre some feet below it. The internal height of this tunnel is altogether rather more than 27 feet, and its greatest width is 24 feet. These dimensions are rarely much exceeded on railways of the ordinary gauge, where two tracks are provided for; and for a single track perhaps 12 feet wide and 16 feet high may be taken as an average. Both the invert and the arch should be built in half-brick rings, care being taken to put in the proper number of bricks to each ring, that the bearing may be uniform. In tunnels of the ordinary dimensions, each ring should contain five more bricks than that immediately within it. The side walls may be built in what is called English bond, consisting of alternate courses of headers and stretchers. The bricks should always be of the best quality, and, when the form of the tunnel requires it, moulded of a taper shape. In the laying also care is requisite, and every brick should be bedded with a wooden mallet, and the joints, if in mortar, well flushed up. The thickness of the lining is regulated by the nature of the ground; but Lecount says that 27 inches at the top and sides, and 18 in the invert, if laid in cement, will be sufficient, even in a quicksand: there are, however, instances of a thickness of 10 rings, or 45 inches. It is sometimes considered advisable to lay the first or inner ring of the roof without mortar, and then to grout it, by which means an equable pressure is insured.

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* As before stated, it was found necessary, in most parts of this tunnel, to increase the thickness of the brickwork from 18 to 27 inches.

A brick drain, built in Roman cement, with the joints left open for about half an inch to admit water from the ballasting, should be laid along the centre of the tunnel; and if the shafts let in water, it should be collected and conducted down the inside of the arch by pipes. Water should be excluded as much as possible during the building of the tunnel and shafts, by puddling with clay, or such other means as the circumstances may dictate; but whatever precautions may be used, water will frequently percolate through the brickwork to a serious extent. At the Chevet tunnel, near Wakefield, this inconvenience has been remedied by lining the roof with sheet zinc. In the Thames tunnel there is an interior lining of cement, behind which channels are provided in the brickwork for the passage of water. A remarkable instance of difficulty arising from this cause occurs in the Beechwood tunnel, 302 yards long, upon the London and North-Western railway. It passes through alternate strata of rock and marl abounding in springs; and, in the first winter after its erection, a chemical action took place, which partially destroyed many of the bricks. It was proposed to line the arch with cement; but an apprehension was entertained that it would not adhere, owing to the constant dropping, and it was determined to apply an interior lining of brickwork, 9 inches thick, and to cut chases in the old work, which, when closed in by the new arch, should become so many drains, 4½ inches square, to conduct the water to the central drain or culvert. The tunnel was divided longitudinally by a temporary partition, and the work was executed in one-half of the tunnel at a time, without stopping the passage in the other half. After executing as much as possible of the brickwork in this way, a series of bearers was laid overhead supporting a close flooring, on which the men stood to complete the arch. The details of this curious operation, which was completed in forty days, in the latter end of the year 1840, were fully detailed by Mr. T. M. Smith, in a paper laid before the Institution of Civil Engineers.

In laying the roadway in a railway tunnel care should be taken to avoid the use of any ballasting of a character likely to retain water. The ballast is sometimes thrown down the shafts on to an inclined plane at the bottom, which conducts it in the right direction. In spreading it, it should be well beaten down with wooden rammers, and the blocks or sleepers should be bedded with great care. As it is especially desirable to avoid all risk of accident in travelling through tunnels, while their darkness might prevent the immediate detection of any derangement of the rails, some engineers, for greater security, place the sleepers or points of support closer together in tunnels than on other parts of the line. The temperature being more uniform than in the open air, renders it easy, with proper care, to provide more accurately than usual for alterations in the length of the rails by expansion and contraction.

Although, in the majority of cases occurring in railway and canal practice, tunnels are constructed in the manner just described, there are exceptions which require notice. In tunnelling near the side of a hill expense is occasionally saved by driving horizontal or nearly horizontal passages, which are called *galleries*, from the face of the hill to the line of the tunnel, and removing the excavated earth through them. The double tunnel through the Shakspere Cliff, near Dover, on the line of the South-Eastern railway, was constructed in this way. A benching or road was formed along the face of the cliff, to afford the means of access for the workmen; and the tunnel was excavated by means of seven galleries opening in the face of the cliff, and inclining towards the sea at the rate of 1 in 176. Their average length was about 400 feet; their width 6 feet, and their height 7 feet; and the excavated chalk was conveyed along them in small tram-waggons, and tipped into the sea. There are also seven vertical shafts of 6 feet diameter, and of an average depth of 180 feet. The tunnel consists of two arches or passages, 12 feet wide, separated by a wall of chalk 10 feet thick; they are about 19 feet high to the springing of the arch, which is of a Pointed or Gothic form, and about 30 feet high in the centre; and each has a single track or line of railway laid through it. The chalk of which the cliff is composed is very hard, but it consists in many places of small detached masses, so that brick lining is required for about two-thirds of the whole length of the tunnel. The arching consists generally of three half-brick rings, and is strengthened at intervals of 12 feet by counter-forts, which are carried up and stepped back, so as to sustain the weight of any flat beds of chalk that appear of doubtful stability.

Another variation from the ordinary process occurs in those tunnels which are formed by means of an open cutting, and subsequently covered in. Such are called *open tunnels*, and are sometimes preferred where the object of the tunnel is to avoid the permanent severance of lands rather than to penetrate ground too elevated for an open cutting. The short tunnel on the London and North-Western railway, at Kensall Green, and parts of the Underground railway, in London, were formed in this way. In such cases the sides of the cutting are made nearly vertical, and supported by timbers until the brickwork is executed.

While the projects for some of the earliest English railways were before parliament, much discussion took place relative to the ventilation and lighting of tunnels, and to the effect which they might have upon the health of persons riding through them. Most of the objections raised against tunnels during the period referred to are now exploded, and some of them appear not a little ridiculous. It was urged by their opponents that the damp cold air common to all subterraneous excavations would prove highly detrimental to health; that the noxious gases emitted from the locomotive engines would accumulate and render the air irrespirable; and that the sudden transitions from light to darkness, and *vice versâ*, would be very injurious to the sight. The discomfort arising from these evils, so far as they really exist, and from the deafening noise of tunnel-travelling, are amply sufficient to give a preference to an open cutting, when such a line is obtainable at moderate expense, but they by no means bear out the predictions of the alarmists. Some interesting experiments made in the tunnel on the Leeds and Selby railway are recorded in a paper by Mr. Walker 'On Ventilating and Lighting Tunnels,' in the 'Transactions of the Institution of Civil Engineers,' vol. i. p. 95. While the tunnel alluded to was in progress, it was determined to leave the working shafts open, to promote ventilation and to admit light. The former object was sufficiently attained to prevent any serious inconvenience to passengers, but, so far as the trains are concerned, little benefit is derived from the light admitted by them, although attempts were made to diffuse it by means of tin reflectors. The experiment succeeded so far as to enable a person to read the larger print in a newspaper advertisement in any part of the tunnel; but it is stated that, owing to the rough and dirty state of the walls and the obliquity of the rays thrown upon them, the rays reflected from them were too feeble to be useful in a case of such sudden transition from the light of day as that experienced by persons passing through with a train. Reflectors would also be rendered useless during the passage of a train by the quantity of steam emitted by the engine. In order to settle the question as to the supposed unhealthiness of tunnels, in February, 1837, Dr. Paris, Dr. Watson, Mr. W. Lawrence, lecturer on anatomy and surgery, Mr. R. Phillips, lecturer on chemistry, and Mr. Lucas, surgeon, were requested to visit and report upon the Primrose Hill tunnel. Although the ventilation was then imperfect, owing to the western extremity of the tunnel being unfinished, and the steam was allowed to escape from the engine for a space of twenty minutes, during which it remained stationary in the tunnel, those gentlemen reported that for so many feet above their heads the atmosphere remained clear, and apparently unaffected by steam or effluvia of any kind, and that neither damp nor cold was perceptible. They further express their opinion "that the dangers incurred in passing through well-constructed tunnels are no greater than those incurred in ordinary travelling upon an open railway or upon a turnpike-road; and that the apprehensions which have been expressed that such tunnels are likely to prove detrimental to the health or inconvenient to the feelings of those who go through them are perfectly groundless." These opinions are fully corroborated by the observations of Drs. Davy, Williamson, and Reid, upon the Leeds and Selby railway tunnel, which, as well as the report on the Primrose Hill tunnel, were given in evidence before the Select Committee of the House of Commons on the London and Brighton railways, in 1837. The objection arising from darkness is obviated on the London and North-Western and many other railways by the use of lamps in the roofs of the carriages, which afford an agreeable though small degree of light in the interior; but in a few cases the tunnels themselves are lighted by gas-lamps attached to the side walls.

The above description of the practical operations of tunnelling is founded upon the methods used by railway engineers; but there is no difference between the execution of a railway or of a canal tunnel. A list of some of the most important tunnels is added, and their cost per yard lineal is affixed wherever it is possible so to do. It may, however, be added that all the works enumerated seem likely to be surpassed in magnitude by the tunnel in course of execution under the Alps of the Mont Cénis range: it is proposed to be about 13,787 yards in length, under a mountain nearly 9000 feet above the level of the rails.

Principal Canal Tunnels.	Length.	Cost per yard.		
	Yards.	£	s.	d.
Thames and Medway	3720	29	6	0
Harecastle (by Brindley)	2880	3	10	8
Lapal (Dudley Canal)	3776			
Gosty Hill (Dudley Canal)	623			
Tipton Green	2926			
Ripley (Cromford Canal)	2966	7	0	0
Blisworth (Grand Junction)	3080	15	13	0
Asperton (Hereford and Gloucester)	1320			
Oxenhall " "	2192			
Marsden (Huddersfield)	5500			
Foulbridge (Leeds and Liverpool)	1640			
Fenny Compton (Oxford)	1188			
Islington (Regent's Canal)	900			
Maida Hill "	370			
Sapperton (Thames and Severn)	4180	39	0	0

PRINCIPAL CANAL TUNNELS.	Length. Yards.	Cost per yard. £	s.	d.
Noirieu (Canal de St. Quentin)	13,128	2	16	0
Soussey (Canal de Bourgogne)	3852	9	2	0
Pouilly (Canal de Bourgogne)	3660	78	15	0
Mauvages (Canal du Marne au Rhin)	5320	65	0	0
St. Aignan (Canal des Ardennes)	288	40	0	0

PRINCIPAL RAILWAY TUNNELS.				
Summit tunnel, Ashton and Manchester Railway	5192			
Box tunnel, Great Western	3227	100	0	0
Littleborough	2869			
Sapperton	2800			
Kilsby	2423	133	0	0
Watford	1793			
Merstham	1780			
White Ball Hill	1470			
Shakespere tunnel	1300			
Primrose Hill	1250			
Bletchingley	1086	80	0	0
Saltwood	1000	140	0	0
Rollebois (Paris and Rouen)	2890	40	0	0
Venables	291	40	0	0
Pissy Poville (Rouen and Havre)	2400	40	0	0
Terre Noire (Lyon)	1641	30	0	0
Cumptich	1017	34	0	0
St. Cloud	554	80	0	0
Nerthe (Avignon to Marseille)	5032			
Blaisy (Lyon)	4376			
Rilly (Rheims)	3829			
Hammarting (Switzerland)	3050			
Hauenstein	2731			

Railway tunnels are usually made about 24 feet wide, and from 23 to 25 feet high, on the narrow gauge; those on the Great Western line are made 30 feet wide by 35 feet high; canal tunnels are rarely executed of larger dimensions than 16 feet 6 inches in breadth by 18 feet in height.

There had been two or three schemes for forming a tunnel under the Thames, prior to that brought forward in 1823 by Mr. (afterwards Sir) Isambard Mark Brunel:—one proposing to connect Gravesend with Tilbury, another to commence at Rotherhithe, a little below the site of the present tunnel; and works had been actually begun at both these places but soon abandoned. Brunel proposed to effect his object by means of a framework or shield, which should support the face of the excavation and allow the earth to be removed on many points simultaneously; the frames or divisions of the shield being then moved slowly forward, and closely followed by a solid mass of brickwork enclosing two arched passages 16 feet 4 inches in height from the invert of the arch, and 13 feet 9 inches span at the springing of the arch. Great difficulties were experienced in the course of the work, and some serious accidents happened from the river breaking through the moist sand and clay through which the tunnel had to be carried. But ultimately all obstacles were overcome, and the work was in 1842 brought to a successful termination, about seventeen years from the commencement of the excavations.

TURBARY, COMMON OF, is a right to dig turf in another man's land, or in the lord's waste. This description of common right may be appendant or appurtenant to a house, but not to land; for the turfs dug in virtue of the right are to be burnt in the house. The right is therefore confined to such quantity as is sufficient for the consumption of the house to which the common of turbary is appendant, and never extends to a right to dig turf for sale.

Where common of turbary is appurtenant to a house, it will pass by a grant of the house with the appurtenances. (2 Rep. 37, *Common.*)

TURBINE. A turbine is a water wheel fixed upon a vertical revolving axis, receiving and discharging water in various directions round its surface. This description of prime mover consists of a drum, bearing a number of suitably formed *vanes*, curved in such a manner as to allow the water leaving them, after it has glanced off from them, to escape with as little velocity or power as possible. Turbines possess the advantage of occupying, comparatively with the power exercised, a very small bulk; and of being equally efficient with large or small falls.

There may be considered to be three classes of turbines: 1st. Those in which the water is supplied and discharged in a direction parallel to the axis; they are technically known as the *parallel-flow turbines*, according to the classification proposed by Professor Rankine, in his 'Treatise on Prime Movers.' 2nd. Those in which the water is supplied and discharged in currents radiating from the axis: or the *outward flow turbines*. And 3rd. Those in which the water is supplied and discharged in currents converging radially towards the axis, or the *inward flow turbines*. The leading principles affecting the working of these various machines are the same, though the details are necessarily dissimilar; they may be briefly described as follows:—

Whatever description of turbine be used, it is desirable that little or no change of velocity of flow should take place in the current, during the passage of the water through the wheel; and that the water should enter without shock, and leave without a whirling motion. The latter condition is attained when the ratio of the entering velocity is to the outgoing velocity in the same ratio as the radius of the receiving to that of the discharging sides; or calling this ratio n, it $=1$, in parallel flow turbines; $\sqrt{2}$ in outward flow turbines; and $\frac{1}{2}$ in inward flow turbines. The angles of obliquity of the blades to the line of flow, differ according to the velocity required in the wheels, and to their peculiar form: thus, in the parallel flow turbines, the angle may vary between 20° and 35°; in the outward flow turbines, between $14\frac{1}{2}°$ and $26\frac{1}{2}°$; and in the inward flow ones, between 36° and 54°, the best velocity at the middle of the rings of the vanes appears to be ascertained by the formula (for all kinds of turbines)—calling v the velocity, h the head in the supply chamber, and g the accelerating force of gravity: then $v = 0{\cdot}655\sqrt{2gh}$.

From General Morin's experiments it would appear that the efficiencies of the respective descriptions of turbines, with reference to the powers exerted upon them, are comprised within the limits of from 75 to 80 per cent. of the power exerted in the parallel flow turbines; in inward flow turbines the limits approach closely the average of 73 per cent.; and in outward flow ones, they are on the average 68 per cent.; on the average then, the efficiency of all classes may be taken to be about 70 per cent. of the total power. The reaction wheel may be considered to constitute a modification of the turbine; and it will be discussed more fully under WATER POWER.

The best descriptions of this class of engines are to be found either in Rankine's work before quoted; in Morin's 'Leçons de Mécanique Pratique;' in Armengaud's 'Traité Pratique des Moteurs Hydrauliques;' and in several of the practical papers on machinery by Mr. Fairbairn. M. Fourneyron has published a description of the outward flow turbines he himself invented, with full instructions for ascertaining the proportions of the several details.

TURF, the sod which covers the surface of pastures, and is composed of a portion of the soil with the roots of natural grasses or other plants; which gives the whole a consistence, and allows of its being raised in slices by the plough, or the paring tool made for the purpose.

The word is often also applied to the substance which is generally called *peat;* and when the latter is taken from the surface where living plants are growing, the name of turf is very applicable to it. It is derived from the Dutch word *torf*, which is generally applied to perfect peat as well as to turf. The origin and composition of peat have been described under that head. [PEAT.] We shall here only notice the uses to which turf is applied, when we mean a sod taken from the surface on which some living plants are still or have lately been growing. Near extensive heaths which have never been reclaimed, and in situations where no regular peat-bogs are to be found, turf becomes a very useful fuel. It is pared off the surface with the heath growing on it, in dry weather, in sods of a convenient size, generally round, and about one foot in diameter. The thickness of the sod depends on the depth and abundance of the roots found in it, as they are the sole cause of the turf continuing to burn when the blaze caused by the burning of the heath is over. As the soil of the places where turf is usually cut is generally of a sandy nature, turf ashes are not so valuable for manuring the land as peat ashes; still they contain portions of potash and other vegetable salts, and produce a very good effect when spread as a top-dressing on moist meadows the soil of which is chiefly composed of clay. In sufficient quantities they are excellent to raise turnips; and it is generally observed that where poor heathy pastures are pared for the purpose of burning the turf on the spot and spreading the ashes, the turnips sown there seldom fail. For the advantages and disadvantages of this operation, see PARING and BURNING.

Where the poor can readily obtain turf for the trouble of cutting it and drying it for use, a degree of comfort is diffused through their cottages which cannot be found where fuel is scarce. In the large open chimney the whole family can be seated by a pile of turf burning on the hearth.

Turf is used for many other purposes, as well as for fuel. Laid like tiles on a roof, overlapping each other, they form an excellent and cheap protection against rain. Cut somewhat thicker, and in the shape of bricks, they serve to build the walls of cabins, which are warm and durable, provided the eaves of the roof project sufficiently to cover them. The soldier who has served through many campaigns knows from experience that a conical hut of turf can be raised in a very short time, if the material is at hand.

When clay is burnt to improve the texture of the soil, the operation is best performed in a circular hearth made of turf, with certain flues to regulate the supply of air to the burning mass. The turf is a slow conductor of heat, and by its means the mass is kept burning steadily in the interior of the heap, without being cooled by the effect of the external air. When the turf-wall itself begins to burn through, it is generally the proper time to mix the whole and extinguish the fire.

The turf which we have been considering is taken from the surface of uncultivated land, and in the course of a certain number of years the wild heaths and other plants natural to the soil spring up again, and by their stems and roots produce a fresh turf. To assist this renovation it is usual to cut the flat turfs of a circular shape with a thin paring tool, as we observed before, so that there remain portions of the surface which are not disturbed, and from which the heath and wild plants soon spread over the surface which has been cut. In this way the same spot may be made to give a fresh supply of turfs every seven years. This is only done where the soil is absolutely barren, and where its cultivation is not thought of; for at last every remnant of good earth is carried off the grasses disappear entirely, and nothing but the common heaths can find food for their vegetation.

The surface of good pastures, especially of commons, is often pared for the purpose of forming an artificial turf for ornament or for the purposes of pasture. In the first case those spots are chosen where the grass is of the finest and closest pile. The surface is pared as thin as can conveniently be done, so that the sward shall not break. A proper spot having been chosen, it is divided by the spade, or some sharp instrument like a knife stuck across a long handle, into strips about a foot wide; and a very sharp flat instrument with a bent handle, so as to work horizontally, is thrust an inch, or a little more, below the surface, paring off the strip which has been marked. As the workman who cuts the sod advances, another rolls it up before him, until it is of a proper size to be carried off. A cut is then made across the strip, and another roll is begun. Thus a large space may be completely bared, or parallel strips may be cut out, leaving some of the turf uncut between them. In this case the loss of the herbage will be soonest repaired by the spreading of the grasses from the strips which are left. When an ornamental lawn is to be formed by laying down the turf, the ground is levelled, or laid in any desired form. It is well rolled and beaten, to make it firm, and, if the weather be dry, it is well watered before the turf is applied. As lawns require frequent mowing, a close, slow-growing turf is a great advantage: it should therefore be taken, if possible, from a poor thin soil. The turf which lies immediately over the chalk is best adapted to this purpose. If the ground to be covered is of a rich quality, it is best to remove the soil and lay some of the poorer subsoil bare, to place the turf on. A rich moist soil would make the grass grow too rank, and require constant mowing and rolling to keep it down. Brickbats and rubbish are often spread over the ground, where a lawn is to be formed by turfing it over: these not only form a poorer soil, but also keep it drier by their porosity. It need not be observed, that where turfing is resorted to, to cover bare places in meadows or pasture, the reverse of all this should be done, and manure spread over the places where the turf is to be laid, so that the roots may be invigorated, and a rich pile of grass may spring up.

When there are banks and inequalities in pastures, it is often useful to pare off all the turf, rolling it up, from the places which are to be levelled. The superfluous soil is then removed, and if it has been long in the form of a dry bank, it is spread over the grass, which it greatly invigorates. The new surface is enriched with manure, if it requires it, and in moist weather or after watering it, the turf is rolled over it and well beaten down. A heavy roller drawn over it will greatly assist its rooting, and thus an unsightly bank, on which the grass was usually either coarse or burnt up, according as the season was wet or dry, becomes a good and neat pasture. Another important use of turf is to cut it into small strips and divide these into pieces of a square inch in size, or somewhat more, for the purpose of laying land to grass by *inoculation*. This is only a partial turfing, which extends rapidly, and in the course of a very few years converts a field which was not very productive as arable land into a valuable meadow, especially if it is so situated as to be capable of occasional irrigation.

The advantage of an extent of fine turf for the exercise of high-bred horses has given a name to the pursuit of breeding and training horses for the purpose of racing. The annals of the turf record the deeds of famous horses and the success of their owners. The turf has its rules and codes of laws, and the highest individuals in the nation often sit in judgment on some disputed point of turf law, with as much gravity as they would decide the most important interests of the state.

TURKISH CHRONOLOGY. The Turks, like all the other Mohammedans, have adopted the æra of the Hijra, which begins with the 16th of July, A.D. 622. [ÆRA.] The year of the Hijra contains 12 months of alternately 30 and 29 days, or, more exactly, 354 days 8 hours, and 48 minutes; and 32 of our (solar) years are equal to 33 Mohammedan (lunar) years, 6 days, 8 hours, and 16 minutes. On these facts is founded the following easy rule for finding the Christian year which corresponds to any given Mohammedan year:—

The number of centuries contained in the given Mohammedan year is multiplied by 3; to the product are added as many units as the period of 33 years is contained in the number of those years which are in the given Mohammedan year besides the centuries; the sum thus obtained is deducted from the given year; and to the rest is added 621, or the number of full Christian years before the beginning of the Hijra: the sum thus obtained corresponds to the Christian year.

Example: What year of Christ corresponds to the Mohammedan year 1188 (peace of Kuchuk Kaïnarjí)?

11 (the number of centuries) × 3 . . . . = 33
2 (the units of the period of 33 years contained in 88) + 33 . . . . = 35
1188 (the given year) − 35 . . . . = 1153
621 (the number of years before the Hijra) + 1153 = 1774

This is correct, the peace of Kuchuk Kaïnarjí having been signed in A.D. 1774.

To change a Christian year into a Mohammedan year requires only an inversion of the preceding rule.

Example: What Mohammedan year corresponds to the Christian year 1774?

1774 − 621 . . . . = 1153
11 (the number of centuries in 1153) × 3 . . = 33
1 (the number of times which 53 contains 33) + 33 . . . . = 34
34 + 1153 . . . . = 1187

We have seen above that the Mohammedan year corresponding to the Christian year 1774 was 1188; but the result is correct notwithstanding the different results in the two cases; for the beginning of A.D. 1774 falls in the latter part of A.H. 1187, and the beginning of A.H. 1188 and the greater part of this year falls in A.D. 1774. Thus the latter rule is only the complement of the first, and by employing both the reader will always know whether a given Mohammedan year falls entirely in one Christian year, or whether it falls in part of one and in part of another Christian year; and he will know the same for a Christian year with regard to a Mohammedan year. If this be true, the consequence will be that, if a Mohammedan year falls entirely in the course of one Christian year, there will be no difference in the result obtained by employing successively both the rules. This is in fact the case, as may be seen by the following example:

The year A.H. 522 begins on the 5th of January, A.D. 1128, and ends on the 24th of December of the same year 1128.

Rule 1—for A.H. 522 : 5 × 3 . . . . . = 15
522 − 15 . . . . = 507
507 + 621 . . . . = 1128
Rule 2—for A.D. 1128 : 1128 − 621 . . . . = 507
5 (centuries) × 3 . . . . . . = 15
15 + 507 . . . . = 522

from which we may conclude that the year 522 A.H. falls entirely in the course of the year 1128 A.D. To make this more intelligible, we observe that the Mohammedan year being composed of lunar or moveable months, its beginning is likewise moveable, and in the course of 33 years it goes successively through all the twelve months of our year. The above-mentioned two rules will be good till A.H. 1401 (A.D. 1980). The determining of the corresponding days of the two eras presents considerable difficulties, and cannot conveniently be given here.

TURKISH LANGUAGES AND LITERATURE. The Turkish languages form a particular family, which differs from the Arabic, the Persian, the Mongol, and the Chinese. The principal Turkish languages are the following:—

1. Uighur. This language is considered the most ancient of all the Turkish dialects, and is still spoken in eastern Turkistán, especially in the country between Káshghar and Kámul. The Uighur was originally written with fourteen, and afterwards with sixteen letters, which, according to Abel Rémusat, are an imitation of the Syriac alphabet, although there is some reason to believe that they have been invented by the Uighurs themselves. They were afterwards adopted by the Mongols, who however have modified them. The Uighur language was cultivated at a very early period, and, as it seems, has had considerable influence on the Chinese literature. The number of foreign words introduced into the Uighur is not very considerable, and this language is consequently the purest of all the Turkish dialects. The Bodleian Library contains a beautiful Uighur manuscript, the 'Bakhliyár-Námeh,' written in A.H. 838 (A.D. 1434). Two other Uighur manuscripts on Mohammedan divinity are in the Royal Library at Paris, and a fourth, the 'Kúdat-ku-bilik,' or 'The Science of Government,' was sent to Paris by Von Hammer Purgstall. This work was computed about A.H. 460 (A.D. 1069), during the reign of Alp-Arslán, sultan of the Seljuks; but the copy of Von Hammer dates only from A.H. 843 (A.D. 1459). The Uighur language is very little known in Europe.

2. Jagatáï, in the greater part of independent Turkistán. This language, which was originally written with the Uighur characters, and which, in ancient times, greatly resembled the Uighur language, is remarkable for its strength, perspicuity, and simplicity. Turkistán, especially Samarkand and Bokhara, having been the centre of the power of the successors of Genghis-khan and Timur, the Jagatáï was cultivated at an early period, and many Arabic and Persian words were introduced into it. The Arabic characters were substituted for the Uighur letters, but not till a considerable time after the Mohammedan religion had been introduced into Turkistán. The Jagatáï language has a valuable literature. The 'Wáki'áti Bábürí' is an autobiography of Sultan Báber, the conqueror of Hindustán (A.H. 900 till 938; A.D. 1494 till 1531). It has been translated into English under the title 'Memoirs of Zehir-ed-dín Muhammed Baber, Emperor of Hindustan, written by himself;' translated partly by the late John Leyden, M.D., and partly by W. Erskine, Esq., 4to., London, 1826. It has also been translated into Persian. The famous 'Genealogical History of the Turks,' by 'Abú-l-ghází (Bahádür Khan, Sultan of Khowaresm), was originally written in the Jagatáï language. The first manuscript of this work known to Europeans was discovered by Swedish officers, who, after the battle of Pultawa, were sent as prisoners to Siberia.

One of them translated it into French, from which language it was retranslated into English, under the title 'The Genealogical History of the Tatars,' which forms the first volume of 'A General History of the Turks, Moguls, and Tatars,' 2 vols. 8vo., London, 1730. The text of 'Abú-l-gházi has been edited by Frähn. (Kazan, 1825.)

3. Kiptshak dialects, in the eastern part of European Russia and Western Siberia. The purest among these dialects is that of Kazan, in which several books have lately been printed. Some of these are much mixed with Finnish words.

4. Kirghiz, the language of the Kárá Kirghiz, and the Kirghiz Kaïsák, who live a nomadic life between the Ural and the Chinese frontier.

5. Caucaso-Danubian, in several subordinate dialects spoken by the Noghaïs, the Kazi-Kumüks, and other Turkish tribes in southern Russia.

6. Turkomán.

7. Austro-Siberian dialects. They are very numerous, and more or less mixed with Mongol or Samoyede words. They are spoken by the Turkish tribes that live in the middle, eastern, and southern parts of Siberia.

8. Chuwash, spoken by the Chuwashes, who live between the Sura and the Wolga, and in some adjacent countries of eastern Russia. The Chuwash differs considerably from the Kiptshak dialects in the neighbouring countries, and it contains a great number of Finnish words. (Schott, 'De Lingua Tschuwaschorum Dissertatio.')

9. Osmanli, or Turkish, commonly called so. This dialect, which is spoken by the Turkish conquerors of the Byzantine empire, must be considered as a compound of the ancient Seljukian language and that of the tribe of the Káyi, from which the Osmanlis are descended. It is the richest and most polished of all the Turkish dialects; and its regularity, precision, and elegance are such, that Jaubert says, if any academy were commissioned to make a language, it would not form one more perfect than the Turkish. Another principal feature of this language is its dignity, with regard to which Sir William Jones says, "The Turkish language has an admirable dignity. The Persian is fit for joyous and amatory subjects, the Arabic for poetry and eloquence, but the Turkish for moral subjects. Turkish is now the the diplomatic and official language not only of Turkey, but Egypt, Tunis, and Tripoli, and formerly of Algiers. The Osmanlis having received their civilisation from the Arabs and the Persians, and the Korán (which among the Mohammedans is never translated from the Arabic into any other language) being still the source of theology and legislation, a great many Persian and Arabic words have gradually found their way into the Turkish language. However the groundwork is Turkish, and the Turks pronounce the Arabic words in a much softer way than the Arabs, a difference which is principally remarkable in the pronunciation of the gutturals and the long vowels.

The Turkish alphabet is composed of thirty-three letters, twenty-eight of which are taken from the Arabic alphabet: four (*pä, chim, yä*, and *ghief*) from the Persian; and one, the "Saghir nún" (*ñ*) is exclusively Turkish. These letters are written from right to left. Turkish is also, and very frequently, written with Armenian characters, especially by the merchants. There is no article, but the demonstrative pronoun "bu" ("that" or "this"), and the cardinal number "bir" ("one") sometimes take its place. There is no gender. The declension of the nouns is easy: the plural is formed by annexing "ler" or "lar" to the word, and there are six cases as in Latin. The adjectives have neither declension nor gender. The declension of the pronouns is analogous to that of the nouns, but not always exactly the same. There are eight kinds of verbs, namely, auxiliary, active, passive, negative, impotential, causative, reciprocal, and personal. The infinitive of all regular verbs is formed by means of the syllables "mek" or "mak;" they become passive by taking the syllable "il" before "mek" or "mak." The verbs have six moods—indicative, imperative, optative, suppositive, conjunctive, and infinitive; and there are five tenses—present, imperfect, preterimperfect, preterperfect, and future. The different kinds of verbs are formed as follows: *sewmek*, to love; ***sewmemek***, not to love; *sewehmemek*, not to be able to love; ***sewilmek***, to be loved; ***sewilmemek***, not to be loved; ***sewilehmemek***, not to be able to be loved; ***sewdürmek***, to make love; ***sewildürmek***, to make that somebody is loved; ***sewishmek***, to love each other; *sewinmek*, to love oneself, &c. There is a considerable number of irregular verbs. The Turkish construction resembles that of the Latin language, and generally a sentence cannot be perfectly understood till the reader comes to the last word. The Turks form new words by means of composition with as much ease as the Greek, the German, and the Persian; in this respect the Turkish language differs radically from the Arabic.

The Turkish literature is of ancient origin. During the reigns of Osman and his successors, a great number of Arabic, Persian, Greek, and Latin works were translated into Turkish. Mohammed II. ordered a translation of Plutarch; Soliman I. had the 'Commentaries' of Cæsar translated; and Aristotle and Euclid were translated in the commencement of Turkish history. Mustafa III. made a translation of the 'Principe' of Machiavelli, and of the 'Anti-Machiavel' of Frederic II., King of Prussia. Some of the works of Boerhaave, Sydenham, Bonnycastle, Vauban, Lalande, Cassini, and, in later times, a great number of English, German, and French works on history, geography, medicine, chemistry, mathematics, and the military sciences, have likewise been translated into Turkish. The original literature of the Turks is valuable, though less so than the Arabic. Jem, the brother, and Selím and Korkud, the sons of Bayazid II.; Soliman II., Ahmed III., and Mustafa III., were distinguished poets, and their works have come down to us. The oldest Turkish poet of renown is 'Ashik-Pasha, who lived during the reign of Osman and Urkhan. The reign of Bayazid II. was distinguished by the following poets:—Nejátí, who was considered the first lyric poet of his time, and who translated several Arabic works into Turkish; Mesíhí, whose 'Ode on the Spring,' translated by Sir W. Jones and by Baron Hammer, is known as one of the finest specimens of poetry; A'fitabí, Munirí, Prince Korkud, and the female poet Mihrí, a native of Amasia. Bakí is the greatest Turkish poet. He was three times high judge of Rúm-ili, and died in A.H. 1008 (A D. 1600); his 'Diwan,' or 'Collection of Poems,' has been translated by Von Hammer, under the title 'Bakí's des grössten Türkischen Lyrikers Diwan,' Vienna, 1825. Nabí Efendi, Seyed Refet, and Rághib-Pasha, were renowned in the past century. Rághib-Pasha, grand-vizír under Osman III., was equally renowned as an historian and a poet, and his countrymen used to call him "the Sultan of the poets of Rúm." The number of historians is very great, and several of them are highly esteemed for their impartiality, judgment, and the concise beauty of their style. Such are 'Ali, the contemporary of Bakí, whose work, 'Kunhol-Akhbár' (Mines of History), finished in A.H. 1006 (A.D. 1597), is one of the best sources concerning the earlier and middle periods of Turkish history; the author speaks with great impartiality about the Christians. Solak-záde has written 'Taríkhí 'Ali Osman li Solak-záde,' a short, but very exact history of the Osmanlis, which finishes with the year A.H. 1054 (A.D. 1644). Pechewí is the author of a history of the period from the accession of Soliman I. (II.) to the year A.H. 1032 (A.D. 1622). Hájí Khalfáh, who died in A.H. 1068 (A.D. 1658), is the author of several excellent works on history and geography, which are written partly in Arabic, partly in Turkish. His 'Takwimuk Tewárikh,' or 'Chronological Tables,' are classical. They were published at Constantinople by the printer Ibráhím, in A.H. 1146 (A.D. 1733), and an Italian translation by Rinaldo Carli was published at Venice as early as 1697. Hájí Khalfah's Geography of Rúm-ili and Bosnia has been translated into German by Von Hammer. From the time of Bayazid II., Turkish history has been written by imperial historiographers, a list of whom is contained in Hammer-Purgstall's 'Geschichte des Osmanischen Reiches,' vol. viii., p. 591-92. The best of these historians are—Edris, or Idris (died in A.H. 930; A.D. 1523); Mustafa Jelal-záde (died in A.H. 940; A.D. 1533); Sead-ed-dín, who became Mufti (died in A.H. 1007; A.D. 1599); 'Abdi-Pasha Nijánjí (died in A.H. 1102; A.D. 1690); Naïma (died in A.H. 1128; A.D. 1715), whose history contains the period from A.H. 1000 till 1070 (A.D. 1592 till 1659); Rashid continued the history till A.H. 1134 (A.D. 1721); 'Asim, the continuator of Rashid, till A.H. 1141 (A D. 1728); Subhí continued it till A.H. 1156 (A.D. 1743); Izí till A.H. 1163 (A.D. 1763); and Wassif till A.H. 1188 (A.D. 1774). The annals of Naïma were published at Constantinople in A.H. 1147 (A.D. 1734); those of Rashid in A.H. 1153 (A.D. 1740); those of Subhí in A.H. 1198 (A.D. 1784); those of Izí in the same year; and those of Wassif in A.H. 1188 (A D. 1774); and afterwards in A.H. 1243 (A.D. 1827). The Annals of Wassif have been partly translated into French by M. Caussin de Perceval.

Among the numerous Turkish biographers, Latifi deserves particular mention. He wrote the lives of about two hundred Turkish poets, one hundred and two of which have been translated into German by Chabert (Zürich, 1800, 8vo). A list of the works published in Turkish, at Constantinople, is contained in Hammer, cited above, vol. vii. p. 583-595; and a continuation of it, which goes down to the year A.D. 1830, in vol. viii., p. 518-523. The 'Wiener Jahrbücher' contain a list of the Turkish works published since A.D. 1830.

Turkish literature has been enriched by numerous works on morals, divinity, and philosophy. Their philosophy, which originated from the famous school at Bokhara, has a mystical character, and resembles in many points the speculative doctrines of Schelling, especially with regard to pantheism. More than one Turkish sheikh has proclaimed the possibility of the identification of the soul with God, and the intellectual re-creation of the world; a doctrine which has likewise been professed by Hegel.

(Toderini, *Letteratura Turcha;* Hammer-Purgstall, *Encyclopädische Uebersicht der Wissenschaften des Orients*, and *Geschichte der Osmanischen Dichtkunst*, 4 vols. 8vo; the *Turkish Grammars* of Davids, of Jaubert, of Hindoglu and of Barker; and the *Dictionaries* of Kieffer, of Bianchi, and of Redhouse; as well as the great *Arabic, Persian and Turkish Dictionary* of Meninski.)

TURMERIC. [Colouring Matters; Curcuma Longa.]

TURNBULL'S BLUE. *Ferricyanide of Iron.* Professor Graham's account of this variety of Prussian blue is nearly as follows:—It is formed by adding ferricyanide of potassium (red prussiate of potash) to a protosalt of iron. It results from the substitution of three equivalents of iron for three equivalents of potassium. The same blue precipitate may be obtained by adding to a protosalt of iron a mixture of yellow prussiate of potash, chloride of soda, and hydrochloric acid. The tint of this blue is lighter and more delicate than that of Prussian blue. It is occasionally used by the calico-printer, who mixes it with perchloride of tin, and prints the mixture, which is in a great measure soluble, upon Turkey red cloth, *raising* the blue colour afterwards by passing the cloth through a solution of chloride of lime, containing an excess of lime. The chief object of this operation is to discharge the red and produce white patterns, where tartaric acid is printed upon the cloth, but it has also the effect incidentally of precipitating the blue pigment and peroxide of tin together on the cloth, by neutralising the chlorine of the perchloride of tin. This blue is believed to resist the action of alkalies longer than ordinary Prussian blue.

TURNER'S YELLOW. *Cassel Yellow: Patent Yellow.* This is an oxychloride of lead, which may be prepared by different processes. When litharge, or the protoxide of lead, is acted upon by a solution of common salt, there are formed soda, which remains dissolved, and a white compound, which is hydrated oxychloride of lead; and this, when heated, loses water, becomes of a yellow colour, and is the compound required. It is composed nearly of one part of chloride and nine parts of oxide of lead: it may also be obtained by heating chloride and oxide of lead together in the requisite proportions, or by heating a mixture of one part of chloride of ammonium with ten parts of protoxide of lead. In fusing these compounds, it is requisite to be extremely careful to avoid any admixture of carbonaceous or combustible matter, as that would reduce a portion of the oxide of lead to its metallic state, which would injure the colour of the product. [LEAD: *Oxychlorides of Lead.*]

TURNING is the art of giving circular forms to articles of wood, ivory, metal, and other materials. The kinds of wood mostly used for common toys are alder, beech, birch, and willow; for the best Tonbridge ware, holly, chesnut, sycamore, apple, pear, and plum; for hard general turnery—beech, box, elm, oak, and walnut; and mahogany and pine for various purposes.

Nearly all kinds of turning are effected by the aid of the *lathe*. The principles of this valuable machine may be summed up in a few words. For every point marked by the workman, it produces a circle; and it may be described as a machine for moving the material to be wrought in such a manner that, being fixed opposite to the tool, any point in the circumference will act upon the whole circle in precisely the same way.

Pole-lathe.—This is the primitive and most simple kind of lathe. It consists of two upright pieces, each having a conical iron or steel point fixed on the side opposite the other, the two points being exactly in a line; one of these uprights, or *puppet-heads*, as they are called, is stationary; the other can be moved along and fixed at any part of the bed by a wedge beneath. The wood to be turned being cut of proper length, the centre of one of its ends is pressed against the point of the fixed puppet; the point of the other puppet is then brought against the centre of the other end, and the puppet wedged firmly in its place. Over the lathe, and at right angles to it, is a long flexible wooden pole or lath, whence the name lathe; one end, fixed firmly overhead; the other, just over the end of the work nearest to the left-hand puppet, has a cord or catgut attached to it, which passes once or twice round the work, and is fastened at the lower end to a treadle. The depression of the treadle and counteraction of the pole give an alternate rotatory motion to the work. The cutting tool is held upon the top of a fixed piece, between the two puppets and close to the work, called a *rest*, but can only be applied during the fall of the treadle; and thus a great loss of time is occasioned. On this account the pole-lathe is now but little used. When commencing, a groove is cut to the extreme left of the work for the cord to work in; and if it is required to use that part, the band is afterwards shifted to a finished part. The beginner has one great difficulty to overcome in turning soft wood. The tool requires to be held firmly almost on the top of the work, and the superfluous material shaved off; while the softness of the wood and the velocity with which it revolves cause the work to be easily spoilt by the least unsteadiness of hand. In other turning, the tool is held nearly opposite to the centre of the work, and the superfluous material is scraped away with little comparative danger of accident.

A modification of the primitive pole-lathe is used by watch-case makers, on account of the facility with which it can be arrested at any point of its rotation. Some case-makers, the French in particular, make use of a large *turning-tool* instead of a lathe. It consists of an iron bar upon which slide three puppets, two to support the mandril with its back screw, and the other the rest; a long steel bow worked by the left hand serves instead of the pole and treadle. This turning-tool works easily, costs but little, and where many workmen are employed effects a great saving of room. Tools of this sort, from six inches to two feet long and upwards, are in use among jewellers, goldsmiths, watch and clockmakers, and many other artificers; and others without any mandril, in which the work is held between two points, as in the pole-lathe. One of this latter sort may be converted into a very useful lathe for small work at a trifling expense, and still answer as a turning-tool if required.

The *Potter's-wheel* is the simplest description of rotatory lathe; but it differs from other lathes in being vertical instead of horizontal. C, *fig.* 1, is an iron crank, upon the lower part of which is placed a heavy foot-wheel, F; the lower end of the crank works upon a centre, P, fixed on the floor; the upper in a collar, B, fastened to the work-bench, A, and supports the turnboard or chuck, D, upon which the clay to be worked is placed. Motion is given to the crank by means of a treadle placed at the back, and connected with the throw of the crank by a hook or rod. For large work the wheel is provided with a winch and bevil gear, and is turned by a boy. [EARTHENWARE.]

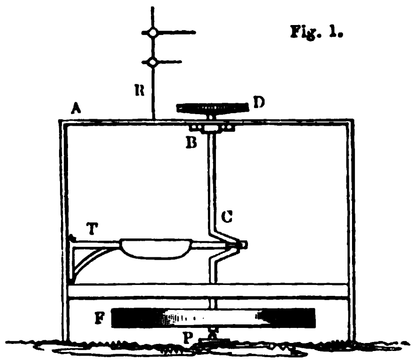


Fig. 1.

Foot-lathe.—*Fig.* 2 is the front-view of a foot lathe, adapted to all ordinary work, whether in metals, ivory or wood. The headstock, H H, is of cast-iron, with a conical steel ring let into the front puppet within which the mandril works. A steel-pointed screw in the back of the headstock keeps the mandril steadily in its place. The beds are of cast-iron, shown in the end view, *fig* 3, which also shows the manner in which the headstock is fitted upon and between the beds, to which it is firmly fastened by two screws, A A, *fig.* 2. The crank, C, is of wrought-iron, supported at each end by a screw, B, *fig.* 2, 3, in the standard of the lathe. The fly or foot wheel, F, has four or five grooves on its edge, and gives motion to the mandril by means of a catgut band, which connects it with the smaller part of the mandril pulley, P. The object of having several grooves upon the wheel and pulley is to allow of the speed of the lathe being regulated according to the sort of work to be turned. But this arrangement only modifies what is called the quick motion. It is frequently necessary that the mandril should move more slowly than the crank; for which purpose a large pulley is placed upon the mandril, and a small one upon the crank, and the two are connected by a band. The treadle is formed of a long iron bar suspended between two points at the back of the frame, D, *fig.* 2 and 3, and carries two shorter transverse bars at right angles, passing under the throws of the crank, and being connected with them by the hooks, E E: the front ends of these two pieces are screwed to the treading-board, W. The standards of the lathe are prevented from altering their position by a rod passing close to the ground, and screwed to each standard at Q. The front-head, G, is of cast-iron fitted on to the beds nearly in the same manner as the headstock. The point of the

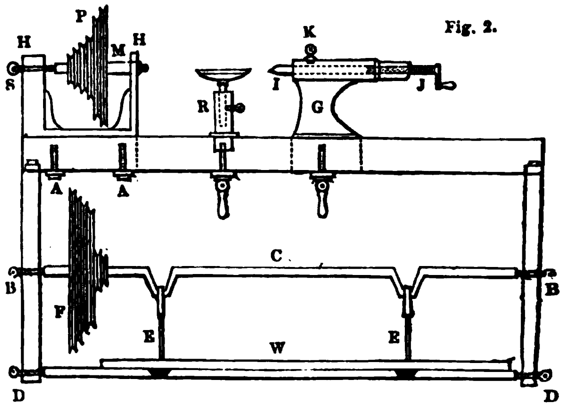


Fig. 2.

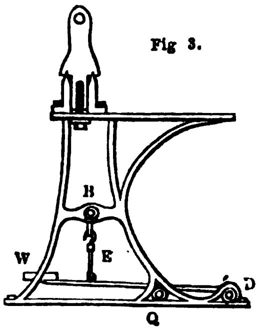


Fig 3.

cylinder, I, to support one end of the work, must be exactly opposite to the centre of the mandril. There are several methods of arranging the cylinder and its screw; but the most convenient is as in the figure, with a screw J, and a winch-handle. K is a small screw with a binding-piece beneath, which rests upon a flat filed on one side of the cylinder, and prevents the latter from shaking during turning. The rest, R, has a jointed lever binding-screw, and several tops to suit different purposes, with a small screw to hold them steadily in the socket.

This completes the lathe itself, but many adaptations are necessary before it is in order for work. Of these the principal are the *chucks* used to connect the work with the lathe. The *screw-chuck* is a circular plate of metal with a boss at the back, tapped to screw upon the nose of the mandril: the face is turned perfectly true, and in the centre is a coarse conical screw to hold any large piece of wood to be turned. The *hollow-chuck* is a strong circular cup of metal with perpendicular sides: the work is either driven into it with a mallet, or, if smaller than the inside of the cup, held by the ends of four screws in its rim. The *drill-chuck* is a strong iron chuck about an inch in diameter, with a square hole in the centre to receive drills and other tools. In drilling, a mark being made with a punch where the hole is to be, the work is held against the point of the drill, and the front-head being brought up to the back of the work, the cylinder is pressed forward, as the drill proceeds, by turning the screw J. The *universal chuck* is a circular disc of metal, with three narrow slits cast in it, extending nearly from the centre to the circumference. The face is turned perfectly true when on the mandril, and the work being laid upon the face of the chuck, is fixed to it by screws which pass through the slits into nuts at the back of the plate. The *concentric chuck* is of the same form as the last described, and the face in like manner must be turned perfectly true to the mandril. Instead of three slits, it has but two, in a straight line with each other, and extending nearly the whole diameter; the opening of these slits is wider at the back than front. Within these slits lies a spindle, having a bearing in the centre and one at each extremity, with a right-hand screw upon one and a corresponding left-hand screw upon the other; these screws move two steel studs which fit accurately within the slits, and have projecting heads about an inch square, that move steadily and smoothly along the face of the chuck. Upon the heads are fitted two other square pieces, having their sides hollowed out in curves of different diameters varying from two to eight or ten inches, and which can be placed with either of their sides towards the centre, to fit the circumference of the work to be held between them.

All the chucks that we have described are adapted principally for work which does not require supporting at both ends. When a long piece of wood is to be turned, a chuck is used having a piece of steel with three points standing out upon its face; the centre of one end of the work is pressed against the middle point, and the other end is supported by the cylinder of the front-head.

The *carrier* is used in metal-work for the same purpose as the three-point chuck for wood. If the ends of the work are pointed, it is supported between the hollow end of the cylinder in the front puppet S, *fig.* 4) and the nose of the mandril, which is similarly shaped for the purpose: if, on the contrary, the ends are hollow, the cylinder is reversed and the point-chuck (*fig.* 5) screwed upon the mandril. The carrier (C, *fig.* 4) is fixed upon the end of the work by its screw, as shown on a larger scale in the side view *fig.* 6; and motion is given to the work by the driver H, *figs.* 4 and 5, either screwed upon the nose of the mandril or attached to the point-chuck.

Fig. 4.

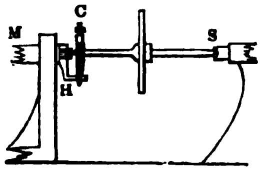


Fig. 5.

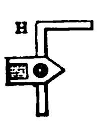
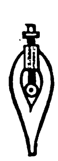
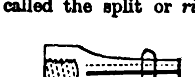


Fig. 6.



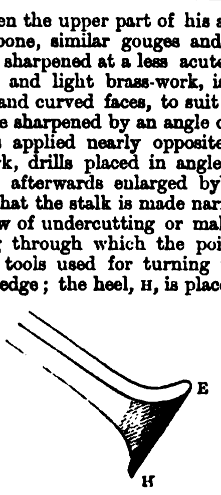
Wood and ivory turners make use principally of box and other wood chucks altered at the instant to suit their purpose. One chuck, however, requires notice, called the split or *ring-chuck*, *fig.* 7: a piece of wood is tapped and screwed on to the mandril and then turned conical; it is afterwards drilled down the centre to the bottom, and two slits cut with a saw at right angles to each other, from the point of the chuck to the nose of the mandril; the work, when in the chuck, is held in its place by the ring on the outside.

Fig. 7.



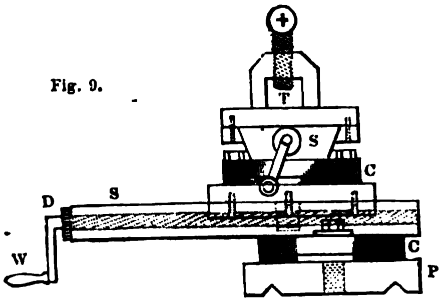
The *tools* used in turning are numerous and varied. For soft wood scarcely any are required besides gouges or round chisels with circular points, to rough out the work, and chisels with an oblique cutting edge, sharpened by being ground and rubbed at a very acute angle on each side. To give the workman power to prevent the tool dipping or trembling, the tools are set in very long handles, the ends of which the turner holds between the upper part of his arm and his side. For hard wood, ivory, and bone, similar gouges and chisels are used; but they are smaller, and sharpened at a less acute angle. Some of the work, as in gold, silver, and light brass-work, is performed by gravers with straight, oblique, and curved faces, to suit different sorts or parts of the work. These are sharpened by an angle on the under side only, and the cutting-edge is applied nearly opposite to the centre of the work. For inside work, drills placed in angles are used to make the first opening, which is afterwards enlarged by other tools with this general characteristic, that the stalk is made narrower than the cutting part of the tool, to allow of undercutting or making the hollow within larger than the opening through which the point of the tool is introduced. The principal tools used for turning iron are the hook-tool, *fig.* 8: E is the cutting-edge; the heel, H, is placed firmly upon the top of the rest and the tool held with both hands, the end of the handle resting against the turner's shoulder. For finishing the work, gravers of different sizes and shapes are used, similar to those for hard wood, gold, silver, brass, and ivory, but stronger, and sharpened at a more obtuse angle. Screw-tools are very important appendages to a lathe, and, with the engineer, in constant use: they are filed up with several teeth exactly the shape of the spaces between the intended threads. For inside screws the teeth are cut on the side, instead of the front of the tool: *taps* however are much more generally used. A circular saw is often fitted to a lathe, particularly for ivory-turning: the saw is placed upon a spindle against a projecting collar, and held in its place by a washer and nut. A parallel rule is fitted upon the table by the side of the saw to regulate the width of the pieces cut off.

Fig. 8.



In the lathe, as previously described, the tool is held in the hand, and is consequently subject to any unsteadiness in the workman. To get rid of this imperfection in certain cases, and so arrange that the tool could be withdrawn at pleasure and replaced in the same position, and always be steady, was a great desideratum. This was effected by the invention of the *slide-rest*, which is now attached to all but the most ordinary kind of lathes. The principle of the slide-rest is that the tool is fastened to a plate, moved in the required direction by means of screws, instead of being held in the hand. *Fig.* 9 shows a very usual and convenient form. T is the place for the tool, which is held down by the screw above: the tools are long square pieces of steel reaching beyond the edges of the plate upon which they are fixed. This plate has two small slips or dovetails screwed on to its under surface and fitting the sides of the plate S, which has a screw along its centre, working in a nut in the upper plate: so that by turning the winch-handle the tool can be moved backward or forward along the plate S, which is about twice the length of the upper or tool plate. Beneath the plate S is a circular piece C, divided by a line into two unequal portions; the upper and thicker portion is screwed to the plate S; the lower is in fact only a circular fillet left upon the plate below: in the centre of the latter is fixed an accurately-turned pin fitting into a corresponding hole in the former, which turns upon it as a centre, and can be set at any required angle to the lower plate (which is graduated for the purpose) and fixed in its position by two binding screws, shown in the figure on each side of S. Beneath are a second slide and circular plate, counterparts of those above, and the whole is mounted on a plate, P. The manner of using the rest will be easily understood. Hollow and spherical surfaces may be cut with the slide-rest with equal accuracy as rectangular figures, either by an adaptation to the common slide-rest, by which the lower slide is made to act upon the other, or by one constructed for the purpose. The slide-rest is of great value in producing any number of pieces of work of exactly the same form, of opposite forms and fitting each other, or in any given proportions; each slide-screw is fitted with a small circular graduated

Fig. 9.



plate, and sometimes also with a micrometer screw and plate, so that the greatest nicety can be observed.

It is, however, only in conjunction with the *power-lathe*, that the full value of the slide-rest is exhibited. The beds, headstock, and slide-rest of the power-lathe, *fig.* 10, are made in the same manner as in the foot-lathe, but stronger; the mandril works in bearings to allow the end B to project beyond the back puppet and carry a toothed wheel; between the beds and along their whole length is a screw, E, which works in a nut attached to the under part of the rest; on the end of the screw is placed another toothed-wheel D, which is turned by the mandril-wheel B by means of the connecting wheel C. By varying the size of the wheels B and D, the rest can be made to move through any required space along the beds of the lathe at each revolution of the mandril. The spindle of the connecting wheel C fits in a curved groove to accommodate it to the different sized wheels used on the mandril and rest-screw; when the rest is required to move in the opposite direction, two connecting wheels are used. The size of these connecting wheels, having no influence on the relative rates of B and D, may be varied according to circumstances. The pulley, instead of being fixed upon the mandril, as in the foot-lathe, is mounted upon a metal tube or cannon which fits and turns smoothly upon the mandril. The lathe, when set in motion, will require no more attention until a fine spiral line is cut, enveloping the cylinder along its whole length; the rest has then to be shifted to where it started from, or by a simple contrivance be made to work its way back again, the tool being set out a little deeper each time until the surface is completed. In screw-cutting with the power-lathe, the point of the tool is made exactly the shape of one of the spaces between the intended threads and having the same rake or inclination; at each revolution of the mandril the rest must move through the distance from one thread to the next. The circumference of the screw has no effect upon any part of the arrangement but the inclination of the tool. When the screw is required to be double or treble-threaded, that is, having two or three intervening spirals upon the same stem, the rest must be moved forward a proportionate distance at the commencement of the second and third threads. In *fig.* 10, F F F is the *drilling-frame*, for working drills and cutters, fixed in the rest, by aid of the pulleys G, H, and I. If it is required to drill any number of holes in a plate, the drill-stock, *fig.* 11, is placed in the slide-rest and connected with the pulley I. By drawing the drill-frame to or from the centre of the work, holes may be drilled in straight lines across the centre, and, by shifting the dividing-plate, in circles; by the combination of the two movements the holes may be placed in curves and spirals in any direction. By giving motion to the mandril, and connecting it with the slide-rest screw, spiral grooves may be drilled upon the surfaces of plates, cylinders, or cones.

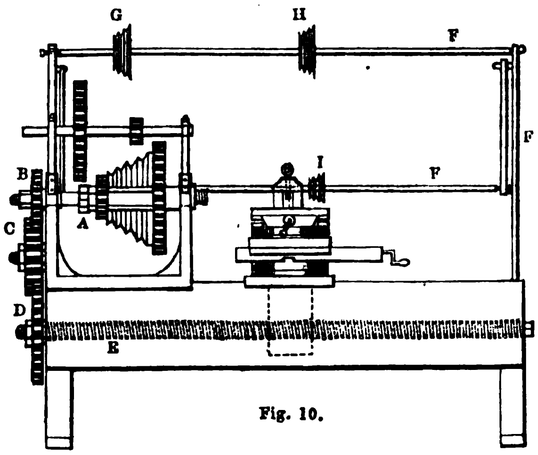


Fig. 10.

Fig. 11.

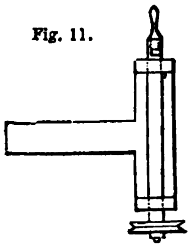
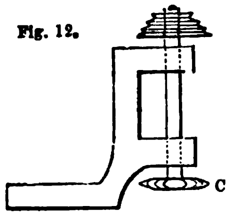


Fig. 12.



We may here notice a contrivance, introduced by Mr. Miles in 1859, for turning pieces of wood so long that they would vibrate or swag if operated upon in the ordinary way. The wood does not rotate. The cutters advance *along* it and turn *round* it, being supported by a travelling carriage. Two dogs or props are placed beneath the wood at certain points, which may be moved out of the way when the cutters approach.

The cutting of toothed wheels is one of the most valuable applications of the lathe. [WHEEL-CUTTING.] The circular cutter used in this process may be employed in many other ways, such as cutting grooves and flutes, which, except for sudden curves, it performs better and much more rapidly than the drill. For cutting straight grooves both the drill and cutter are entirely superseded by the *planing-machine*, a modern invention of the greatest importance. It supplies what was one of the greatest wants of the engineer, and might appropriately be called the *straight-lathe*. For cutting grooves or flutes in cylindrical work, two small puppets carrying centres are screwed to the table to support the work, and the parts where the grooves are required are brought under the tool by means of a division-plate fixed to one of the puppets: a revolving cutter may be used instead of a fixed tool for cutting long pinions and terminating flutes.

Excentric Turning.—In enumerating the different chucks, we purposely omitted the *excentric* and *oval*, as they give their names to the respective kinds of turning for which they are used, and may therefore be considered rather as parts of the lathe itself than as mere appurtenances. *Fig.* 13 represents a *single* excentric chuck. It consists of a strong plate which screws on the nose of the mandril; two dovetailed pieces are screwed upon it near the edges, between which the slide, S, works. Upon the slide is fitted a circular plate, which turns upon a centre, and has its edge cut into a number of teeth according to the size of the chuck; C is a click with one or two teeth fitting between the teeth of the wheel, and held in its place by a spring under the other end. The nose, N, for carrying the work, is fixed to the upper plate. The *double* excentric chuck is made in the same manner, but it has a second slide, at right angles to the first, on the back of the ground plate. In common turning the use of the excentric chuck is to bring any required point in the work in a line with the centre of the mandril; thus circular holes may be cut in any part of a plate, the edge may be hollowed out by any number of curves of the same or different radii, and polygons with curvilinear sides may be produced with the greatest accuracy. *Figs.* 14, 15, and 16 represent three among an infinite variety of figures produced in this way. In ornamental turning the excentric chuck is mostly used for cutting patterns upon the surface of the work without altering its general outline. Thus, in ornamenting ivory or wood-work, circles and curves are laid in an infinite variety of positions upon the face and edges of the work. The ivory-turner frequently uses a small instrument called an *excentric cutter*; it is formed like the drill-stock, *fig.* 11, and moved by a bow; the cutting point can be fixed at different distances from the centre by means of a groove and screw. In conjunction with a click plate upon the mandril, the cutter answers many of the purposes of the single excentric chuck. With the single-slide excentric chuck and the mandril at rest, the cutter will produce patterns which would otherwise require the double excentric.

Fig. 13.

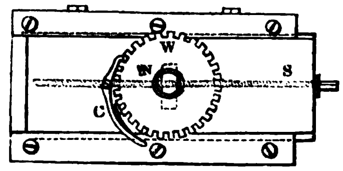


Fig. 14.

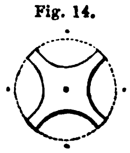


Fig. 15.

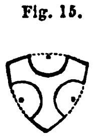


Fig. 16.

Geometric Turning.—When the work revolves on the lathe, and the excentric cutter is driven by a band in connection with the mandril, a great variety of very complicated and beautiful epicycloidal and other curves may be cut. This geometric chuck is an excentric chuck with the addition of an arrangement for giving motion to the work upon the chuck, and independent of the mandril. Fixed to the headstock and concentric with the mandril is a toothed wheel which, as the chuck revolves, drives another and smaller wheel on its under surface: this latter is connected with another toothed wheel which causes the click-plate and work to revolve. The patterns may be infinitely varied by altering the relative sizes of the wheels; and by introducing an extra wheel, and so causing the work and chuck to revolve in opposite directions at the same time; and lastly by changing the position of the tool. The number of different curves that can be produced by these changes and the great dissimilarity to each other can hardly be conceived. The excentric and geometric chucks are much used in producing patterns on plates and blocks for printing and embossing.

Oval Turning.—Until the invention of the oval chuck the production of true ovals was a matter of considerable difficulty, and the cutting of them upon the lathe an impossibility; with it we can turn ovals of all sizes and proportions with almost the same ease as circles. The construction of the chuck is simple. Upon the front of the headstock, H, *fig.* 17, is placed a ring, held by screws through its two arms and the projecting pieces on each side of the headstock; a screw is placed in one arm of the ring to draw it out excentric to the mandril. *Fig.* 18 shows the front of the chuck with a slide moving between dovetails on a ground-plate; the ground-plate, as shown in *fig.* 19, has two slits cut from the centre boss, which screws on to the mandril, nearly to the circumference; two small studs are cast upon the back of the slide, which are made to work easily in the two slits, and stand up just above the face of the ground-plate. When the slide is in its place two steel rubbers with straight polished faces are screwed to the studs, and stand out at the back of the ground-plate at right angles to the slits, as seen in *fig.* 19. The ring being fixed in its place upon the headstock, the chuck is screwed upon the mandril, the rubbers clasping the ring, which must be kept perfectly smooth and well oiled; the excentricity of the ring, acting upon the rubbers, draws the slide out of the centre in opposite directions alternately, and upon the tool being applied an oval will be described upon the face of the work, having the shorter diameter in proportion to the distance of the tool from the centre, and the longer to the excentricity of the ring. For ornamental work the oval chuck is provided with a click and sometimes a micrometer plate, like the excentric chuck, for placing the ovals in different directions.

Fig. 17.

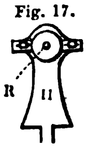


Fig. 18.

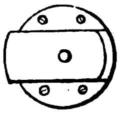
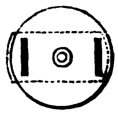


Fig. 19.



Rose-engine Turning.—Of all the different sorts of ornamental turning this is by far the best adapted for embellishing small articles. It is in very general use for gold, silver, and gilt-work; it is besides applied to the production of ground tints, borders, and ornaments on copper, steel, and wood rollers for printing and embossing calico, leather, and paper; and many other sorts of ornamental work. An unsteady lathe, which in revolving produces an irregular circle, is a rude approach to the rose-engine, and may very possibly have furnished the first hint for its invention. We shall now describe it. H (*fig.* 20) is a headstock, supported upon the conical points of two screws, C C, in the two metal standards, A A, fitted and bolted to the bench or bed. In the front and back of the headstock, near the bottom, are two sunk centres to receive the conical points of the screws. The screws are secured by washers that run upon them, and tighten against the standards. The upper part of each standard carries two other screws at right angles to those described, for the purpose of holding the headstock steady when the rose-engine is to be used as a common lathe. Two of these screws are shown in the front of the engine (*fig.* 21). Upon the mandril are mounted the pattern guides, or rosettes, circular plates of gun-metal or brass, each about half an inch thick, and having two patterns or waves upon its rim. The rosettes are of two sorts, fixed and shifting. The fixed, F, are screwed to a collar turned upon the mandril itself; the moveable, R, are fixed upon a cannon, B (*fig.* 20); the plate M is fixed to the cannon, and the rosettes are prevented from turning by a feather which fits into a notch in each of the rosettes: a nut at the end of the cannon screws all tight against the plate M. The plate D is put on the mandril at the back of the cannon plate M, but independent of both; behind this is another plate, P, fitted on to the mandril, and turning with it; at the back of this plate is a nut, which is tightened until the cannon requires some little force to turn it upon the mandril with the hand. On the large plate P, is a spring-click, which falls into notches cut in the plate D, which itself carries an endless screw working into a half thread cut on the edge of the cannon plate M. T is a carriage for holding the rubber R, by means of the two screws in the top of the carriage: the rubber is a small bar of steel, three or four inches long, and the breadth of the rosettes. Screwed into the bottom of the headstock is a strong arm, *h* (*fig.* 21), with a square hole near the bottom, to receive a smaller arm pierced with holes; one end of this latter is attached to a strong spring, S, and by placing a pin in one or other of the holes in the small arm, the spring may be made either to press or pull the arm *h* with less or greater force. The rubber-carriage T being moved along the bar B till the end of the rubber is exactly opposite the face of the rosette to be employed, and fixed there by the back-screw, the spring set to *pull* the arm *h*, and the side screws in the standards A turned back until the face of the rosette rests upon the rubber R, the engine at each revolution will produce a copy of the indentations upon the face of the rosette. The engine is moved by a hand-winch with a band passing round a foot-wheel, and another connecting a small pulley on the crank with the mandril-pulley E, in the same manner as the slow motion of the foot-lathe (*fig.* 2). The slide-rest is adapted to the rose-engine in the following way. The tail-piece of the rest F (*figs.* 20, 22) has a hollow cylinder, C, fixed in the middle of one end. The bar B, which has a piece at each end fitting into dovetails in the sides of A, has a cylindrical piece which fits accurately into the hollow cylinder C, and can be raised or lowered at pleasure by a ring or nut, N, working upon the outside of C, the rest being placed in the required position, and fixed to the bench by the screw S (*fig.* 20). The stock A moves round upon the cylinder C, and can be fixed at any required angle by the binding nut O. The top of the rest, which traverses along the bar B, by means of a screw throughout its length, provided with an index-plate and winch-handle, S, is composed of two parts, the ground plate (*fig.* 23) and another plate (*fig.* 24), which carries the tool-slide. The engine is also capable of turning the sides and edges of work, for which purpose it is provided with a separate set of waves cut upon the sides of the rosettes, some of which are made of larger diameter than others for that purpose. The rubbers are shaped at the side to correspond; the mandril has an endway-motion within its bearings, and is acted upon in either direction by the lever-spring G (*fig.* 20), which has its fulcrum upon the bench: its upper end is forked, and fits a groove in the mandril, and the lower held by an arm and pin. For side-work the slide-rest is placed parallel with the bench as in common turning.

Fig. 20.

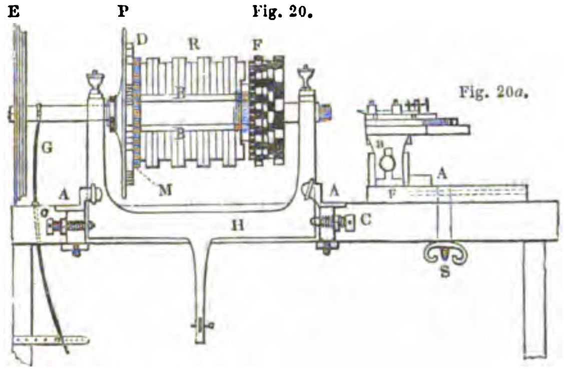


Fig. 21.

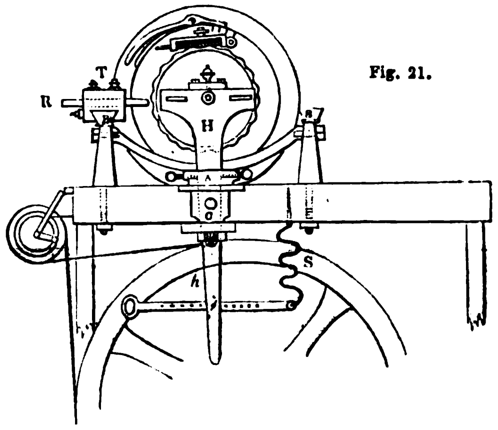


Fig. 22.

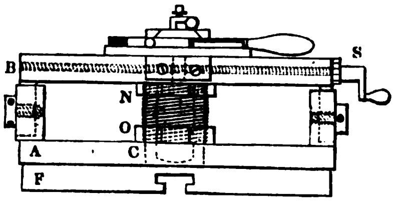


Fig. 23.

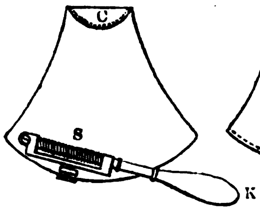
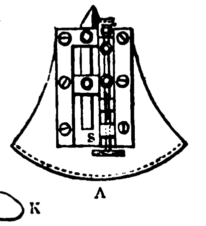


Fig. 24.



The *square*, or *straight-line chuck*, is peculiar to the rose-engine, and forms a very material part of it; the object of it is to lay the patterns in a straight instead of a circular direction. *Fig.* 25 represents the straight-line chuck; the square frame, A A, is fastened to the two arms of the headstock, shown in *fig.* 21, by bolts and nuts, or wedges; B, B, is a slide connected with the nose of the mandril either by a chain or, what is better, a rack and pinion. On the face of the slide are

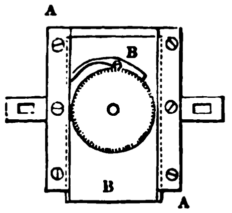
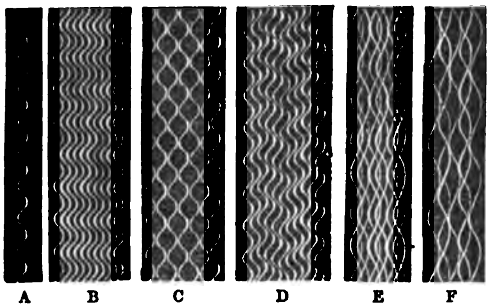


Fig. 25.

click and screw-plates, and a nose to receive the chucks, as in the excentric and oval chucks. A, *fig.* 26, is the wave of which the patterns

Fig. 26.



B, C, D, E, and F are composed, by notches in the plate. These specimens will serve to show the immense number of patterns which may be produced with twenty or thirty rosettes and their combinations. Many curious patterns are produced by using two rosettes, one fixed to the mandril, the other on the cannon. For cutting copper and steel-plates, or wood blocks, the tool is sharpened with two acute angles; but in turning gold and silver work the quantity of metal taken off is required to be so minute that the two faces of the tool must be rubbed to such an obtuse angle as to appear almost straight. Close to the side of the tool in the rest is placed a stop, or touche, as it is called, to regulate the depth of the cut. The touche has a very small face, highly polished, which rubs upon the work in advance of the tool.

The number of adaptations, on account of the various and irregular shapes of the different pieces of work to be engine-turned, is very large, and would take up far too much space to describe. Cutting the rosettes, which every engine-turner ought to do for himself, is an operation of considerable nicety, as the waves are mostly very shallow, and the rosettes large, to make them work easily, and the slightest fault in a wave will be repeated through the whole work. Two superior machines for engine-turning were invented by Messrs. Perkins and Heath, some years ago, in which the rosettes are dispensed with, and their place supplied by an excentric wheel, or cam, which produces one wave only; but by means of toothed wheels, as many of these waves as are requisite are introduced during each revolution of the mandril. This engine produces an immense variety of patterns, with the very great advantage of all the waves being precise counterparts of each other. Work of this description is generally cut with a diamond, as a steel tool is liable to break, or get dull, and destroy the uniformity of the effect.

TURNIPS. *Brassica rapa.* This well-known plant is cultivated for its bulbous roots both in the garden and the field. As a culinary root it has been prized from the earliest times, and many varieties have been cultivated for the table; but it is those of a larger kind, cultivated in the fields, which form so important a part of the most improved systems of agriculture on all light soils, that the success of the farmer is, in general, proportioned to the quantity of turnips raised on his farm. They are the great foundation of all the best systems of cropping, by supplying the manure required for the subsequent crop, and, at the same time, clearing the land of all noxious weeds, by the numerous ploughings, stirrings, and hoeings which they require.

Turnips were first raised upon land which had already borne a crop that was reaped early in summer, and on fallows which had been worked and cleared early, so as to leave a sufficient interval between the last ploughing and the time of sowing winter corn to have a tolerable crop of turnips. These turnips however, which are still cultivated by the name of stubble or eddish turnips, never grow so large as those which had been sown earlier on land well prepared and highly manured.

The regular cultivation of turnips on a large scale was originally introduced from Flanders into Norfolk two centuries ago, and from Norfolk was carried into the south of Scotland and the north of England about a century after. It was long confined to one or two individuals, who cultivated turnips very successfully; but at last it spread, and was greatly improved by introducing the row culture, according to Tull's system, which acquired the name of the Northumberland mode of cultivation. The usual mode of sowing turnips both in Flanders and in Norfolk was broadcast, and, as the labourers in both countries became very expert in hoeing them out at regular distances, this mode was long preferred. All farmers however, who have any pretensions to a good system of cultivation, now adopt the Northumberland plan. The great object on poor light lands, especially those which have lately been brought into cultivation, is to raise a crop of turnips: for when once this is obtained, and the land has been improved by the folding of sheep upon it, there is no great difficulty in maintaining the fertility thus produced by judicious management and frequent green crops. Great improvement in poor soils has been effected by the introduction of ground bones and superphosphate as a manure. It is however the best plan to unite the regular application of farm-yard dung with that of the bone-dust. For this purpose the best farmers prepare their land, where they intend to sow turnips, early after harvest, by giving it as complete a cultivation as they can before winter; and they put on it a good coat of manure, and plough it in. In the beginning of summer another ploughing is given, with repeated harrowings, to destroy the weeds which have sprung up. If the subsoil is dry, or the land has been thoroughly drained, the seed may be drilled in rows from 2 feet to 30 inches apart, with bones or any equivalent artificial manure on the flat surface. The turnip-seed can scarcely fail to vegetate soon: less danger arises from dry weather than if they were on the top of a ridge, and the intervals can be readily stirred by horse-drawn tools. The manure, which has had time to incorporate with the soil and to impart to it the various products of its decomposition, is in the best state to nourish the young plant, until it can push forth its roots and feed, as it were, on the bone-dust: a more rapid growth is ensured, which is the best preservative against the fly; and experience has proved that this is a much more certain way to insure a good crop of turnips, especially of swedes, than the old method of putting all the manure immediately under the seed in the rows, where it often remains inert if dry weather comes on soon after the seed is sown. The quantity of manure put on in autumn, or very early in spring, depends on the means of the farm: if ten cubic yards of short dung can be afforded per acre, the crop of turnips will amply repay it, and twenty bushels of bone-dust or less per acre will be sufficient to drill with the seed. Long fresh manure may be safely ploughed in before winter, which would be very improper in a light soil if used in summer. This will be rotten before the turnips are sown, and all the expense of forming dunghills and turning them over is saved. There is no danger of the manure being wasted; for whatever weeds may be produced will be ploughed in and returned to the soil. All the nutritious parts of the decomposing dung will be absorbed by the earth, and none of them will evaporate. Where farm-yard manure is scarce, half the above quantity may be used, and a fair crop of turnips may still be expected.

The early vegetation of the seed is essential to a good crop of turnips. In its young and tender state it is liable to a variety of accidents. Its great enemy is the turnip-fly (*altica nemorum*), which appears always in great quantities, if there is any continuance of dry weather. The more frequently turnips are sown on the same ground the more abundant is the fly, but where the surface has been pared and burned there is seldom any loss from this cause. It is generally found that in moist weather the fly does comparatively little harm, as then the vegetation is rapid, and the plant, when once it has put forth its rough leaves, is considered safe. Whatever therefore accelerates the vegetation, will secure the growth of the turnip. Hence the advantage of dunging the soil before winter, by which means it is enriched uniformly, and a great portion of the manure, having become soluble, absorbs moisture from the atmosphere. And in dry weather it is well to sow the seed with the water drill. As soon as the turnip-plant has put forth its rough leaves, the intervals between the rows should be stirred with a light plough drawn by one horse. The plough can be made to go within an inch or two of the plants, throwing the earth from the row into the interval: a small harrow, which can be set to any required width, is then drawn between the rows to loosen the earth raised by the plough. This greatly increases the absorption of moisture and invigorates the young plants. They may now be thinned out and even singled in the rows by means of a hoe about 12 inches broad, leaving plants a foot or more apart. Thus the turnips are left at a proper distance, and, having ample room, will soon cover the rows. A horse-hoe is now drawn between the rows to eradicate all weeds and keep the soil open for the fibres of the roots to shoot in. It is not advisable to throw the earth over the turnips, unless it be just before winter, to protect them from the frost; on the contrary, in wet weather the earth is more likely to cause the turnip to rot than to help its growth. The fibres which draw the nourishment strike in the soil below, and spread between the rows wherever they meet with a loose and mellow earth.

In order to have a heavy crop, especially of Swedish turnips, it is advisable to sow the seed early, that is, in southern counties, towards the end of May. They will then have the advantage of the summer showers, and be beyond the reach of the fly in a very few days, and when the dry weather sets in they will already have a supply of moisture in their roots, and the fibres, having struck deep, will not suffer any check. The only inconvenience of sowing early is that many of the plants are apt to run to seed. This is in many cases owing to the seed which is used. If the seed has been raised from fine roots which have stood the winter, there is little danger of the plants running to seed in the first summer; but, as is often the case, if small imperfect roots are taken, or those which run to seed in autumn, then the plants will have a tendency to produce seed and not bulbs. The white Norfolk turnip and its varieties should be sown about midsummer to have a good and heavy crop before winter. The distance at which they may be left in thinning them out must depend on the variety, whether it has a wide spreading top or not. The best crops both of swedes and common field turnips are generally those where the tops are vigorous and moderately spreading. A small top will not nourish a large bulb: but when the growth is chiefly in the leaves, the bulbs are seldom large.

It may be considered as a general rule, that the most advantageous mode of consuming turnips is to draw them and cut them in slices in the field, to be there consumed in troughs by sheep, to which corn or oil-cake, as well as hay, is regularly given. When the crop of turnips is abundant, part of them may be stored for the cattle in the yard or fatting-stalls, and for the milch-cows and heifers. They will require nothing but good straw, if they have plenty of turnips, and no hay whatever need be used, unless it be for the horses; and even they will thrive well on Swedish turnips and straw with a small quantity of oats.

Turnips are often left in the field all the winter, which greatly deteriorates them. If they cannot all be fed off before Christmas, they should be taken up, and the tops being cut off within an inch of the crown of the root, they may be stored in long clamps five feet wide and four feet high, sloped like the roof of a house and covered with straw and earth, in which state they will keep till they are wanted. It is advantageous to have different varieties of turnips, which will come to perfection in succession; and it is useful to sow some at different times for this purpose. The small turnip, which from its rapid growth is called the nimble turnip, may be sown as late as the end of August, and in mild seasons will produce tolerable bulbs in winter and early in spring. The frost will not injure a growing turnip so readily as one which is come to perfection and the leaves of which are withered. Some varieties, like the yellow Aberdeen and the green round turnip, are hardier than others, and will stand the winter well in a light and dry soil.

There are so many varieties cultivated, that it is difficult to enumerate them. The Swedish turnips may be classed according to the colour and size of their tops and the shape of the bulb. The best have but little stem rising from the bulb and a good tuft of leaves. The substance of the turnips is of a bright yellow and has a strong smell, especially when they have been kept some time. No frost will hurt them, if they are kept dry; but alternate rain and frost will do them harm. When they are stored, it is advantageous that the air should have free access; and for this purpose it has been recommended to place them between hurdles set upright and to slightly thatch them with straw to keep out the rain. In this way they keep longer sound than when put in clamps covered with straw and earth.

Of the field turnip there are numerous varieties. The common Norfolk turnip is round and flat, the bulb being half buried in the ground; it throws out no fibres, except from the slender root which proceeds from the centre of the bulb. There is a subvariety which is reddish at the insertion of the leaves, and another of a green hue: the latter is the hardiest. The globe turnip takes its name from its shape; it rises more out of the ground, and grows to a greater size; like the last it is either entirely white or red or green near the crown. It is on the whole the most productive and hardy. The tankard turnip rises high out of the ground, and approaches in shape to the mangel-wurzel. It grows to the greatest size; but it is apt to become spongy if left long on the ground, and its weight is not in proportion to its bulk. There are red tankards and green tankards, as well as white. The green round turnip is considered very hardy, and is usually sown late, to be consumed after the winter. The yellow Aberdeen, although somewhat less, is compact, and stands the winter well: it is a very useful variety.

Those who are possessed of a good variety will do well to raise their own seed, as that which is bought cannot always be depended upon; the best-shaped middle-sized bulbs should be chosen, the leaves being cut off not nearer than an inch from the crown. They should be planted in a mellow soil, in rows three feet wide, and a foot from bulb to bulb in the rows, about March or April. When the pods are well filled with seeds, and these are round and hard, the stem should be cut close to the root and carefully laid under a shed to dry. The seed will ripen there without shedding, and when the pods are quite dry, the seed is easily beaten out with a stick or light flail. Birds are so fond of it, that a constant watch must be kept, and this is the reason why so few farmers grow their own seed. Turnip seed is often raised in the gardens of cottagers, whose children keep off the birds, and it is a branch of industry which every farmer should encourage. He can readily see that good bulbs only are used, and he secures the seeds he wants, while the cottager is well paid for his trouble. This is perhaps the most convenient mode of raising the seed on a large farm. It is best to use fresh seed, as it always germinates sooner. Machines which sow the seed and manure in drills at the same time may be had of most of the manufacturers of improved agricultural implements.

TURNPIKE ROADS. [ROADS.]

TURNPIKE TRUSTS. Turnpike-roads are a peculiar species of highways placed by the authority of acts of parliament under the management of trustees or commissioners, who are invested with certain powers for the construction, management, and repair of such roads.

Besides the various local acts, there are several acts of parliament called General Turnpike Acts, the provisions of which extend and apply to all existing and subsequent local acts, and which are too numerous for citation here. The General Highway Act (5 & 6 Wm. IV. c. 50) also contains certain provisions applicable to turnpike-roads; but, by the 113th section, does not extend to them except where expressly mentioned.

The trustees of turnpike-roads consist of persons nominated for that purpose in the Local Acts, who must be persons possessed of a certain property qualification, and of the justices of peace of the county or counties through which the roads pass; but all persons who are contractors or otherwise personally interested in the roads are disqualified from being trustees. (3 Geo. IV. c. 126, ss. 61, 62, *et seq.*) They are exempt from personal liability for acts done in pursuance of their powers, and may sue and be sued in the name of their clerk. (7 & 8 Geo. IV. c. 24, ss. 2 & 3; 3 Geo. IV. c. 126, s. 74.)

For the purpose of providing the necessary funds for making and maintaining the roads under their charge, trustees are usually empowered to receive moneys by way of subscription, upon which interest is payable to the subscribers out of the produce of the tolls which the trustees are by the local acts empowered to levy upon persons using the roads. Power is also given them to borrow money upon mortgage of the tolls. (3 Geo. IV. c. 126, s. 81.)

The enactments of the General Highway Act (5 & 6 Wm. IV. c. 50, s. 94), relating to summary proceedings before justices to compel repairs of highways, extend the jurisdiction of the justices to turnpike officers, where the highway out of repair is part of a turnpike-road; and while the liability to statute labour existed, it was exigible as well in respect of turnpike-roads as other highways; but the obligation of statute labour seems to be now entirely abolished by the repeal, in the 5 & 6 Wm. IV. c. 50, of the statutes under which statute labour was compounded for.

The amounts of toll exigible on any turnpike road are regulated by the table of tolls which is contained in the local act by which the trust is constituted, and no tolls can be charged except such as are given by clear and unambiguous language in the Act; and there are various cases of exceptions.

Tolls upon turnpike-roads are in most cases made payable once a day only at any one gate, and payment at one gate generally gives exemption from payment at other gates within a certain distance. Post-horses having passed through any gate may return toll-free before nine o'clock in the morning of the following day, and when horses, having passed through a gate, return the same day or within eight hours, drawing a carriage, the toll paid on the horses is to be deducted. (3 Geo. IV. c. 126, ss. 29, 30.)

The General Turnpike Acts contain various provisions regulating the weights to be allowed to carriages passing along turnpike-roads, and imposing additional tolls for overweight, and also provisions regulating the amount of toll leviable upon waggons and carts depending upon the construction, breadth, and tire of their wheels. (3 Geo. IV. ss. 7, 9, &c.; 4 Geo. IV. c. 95, ss. 2, 5, &c.)

Trustees are enabled to erect toll-gates and toll-houses, the property in which is vested in them, and are required to put up at every toll-gate a table of the tolls leviable thereat, and to provide tickets denoting payment of toll to be delivered to persons paying the same. (9 Geo. IV. c. 77, s. 3, &c.; 3 Geo. IV. c. 126, ss. 37, 60; and 4 Geo. IV. c. 95, s. 28.) The remedies for the recovery of tolls, and the penalties for evading them are contained in 3 Geo. IV. c. 126, s. 39, &c.

The trustees of every turnpike-road have power to enter into compositions for any term not exceeding a year at a time, with any person for tolls payable at any toll-gates under their management. (4 Geo. IV. c. 95, s. 13.) They may also, though not empowered to do so by the local act, reduce the tolls leviable under the authority of the act, and advance them again to any amount not exceeding the rates authorised by the act; provided that where money has been borrowed on the credit of the tolls, no reduction shall be made without the consent of the persons entitled to five-sixths of the money due. (3 Geo. IV. c. 126, ss. 43, 44.) Trustees may also farm out the tolls, though no express power be given in the local act.

The General Turnpike Acts contain, besides numerous provisions with respect to the appointment and duties of officers, the meetings and proceedings of trustees, the making of causeways, ditches, and drains, the erection of milestones, the watering of roads, the prevention and removal of annoyances and nuisances, the marking of carriages and regulations as to drivers, the apprehension of offenders, the recovery and application of penalties, the limitation of actions, &c.; all which general enactments have been made from time to time for the purpose of shortening and lessening the expense of private road bills, so that almost the only objects which now require to be attended to in the construction of road acts are the appointment of trustees, the number and situations of toll-gates, and the amounts of tolls. (Chitty's 'Statutes,' vol ii., *Highways.*

TURNSOLE, or TOURNSOLE. [ARCHIL; COLOURING MATTERS.]

TURPENTINE. The well-known liquid to which the word turpentine is now so commonly applied, is only the volatile portion of turentine properly so called. True turpentine is really an oleo-resin, a liquid of about the consistence of honey. It flows naturally, or by incision, from the wood of most coniferous trees, such as pine, larch, fir, pistachia, &c., and by distillation yields spirit, essence, or volatile *oil of turpentine,* the non-volatile portion being common *resin,* or *colophony.* [RESINS.] Oil of turpentine is very largely used in the preparation of paints and varnishes, and also, when rectified, for burning in lamps under the name of camphin. The derivation of the word turpentine is not very evident. It was known and described by Marcus Græcus in the eighth century.

The turpentine met with in English commerce is nearly all imported from the States of America, North Carolina and Virginia supplying the greater part. It is the produce of *Pinus palustris, P. tæda,* and *P. abies.* French or Bordeaux turpentine is mainly obtained from *Pinus maritima,* a tree growing abundantly on the coasts of Southern Europe.

The method of procuring turpentine is very simple. An incision, or hole, is made in the bark of the tree, or a small piece of the bark is removed, in the spring of the year. From this wound the turpentine slowly exudes, and is collected either in a little trough attached to the stem, in a hollow made at the foot of the tree, or by some similar contrivance. It is from time to time transferred to casks made to hold about 2 cwt. The first gathering is sometimes called *virgin turpentine,* and contains about 20 per cent. of oil; that collected towards the end of the season, in October, has a more solid but still soft consistence, and is not so rich in oil. As might be expected, the crude turpentine frequently contains portions of twigs, chips, and leaves; these are sometimes separated by straining the melted turpentine, and the latter is then termed *refined.* *Venice turpentine* is the variety produced from the larch tree (*Larix Europæa*); *Canadian turpentine,* or *Canada balsam,* exudes from the *Abies balsamea;* and *Chian turpentine* is obtained from the *Pistacia terebinthus.*

Turpentine slowly hardens when exposed to the air. This is partly due to evaporation of the more liquid portion, and partly to resinification of the fluid part by oxidation. It is probable that in the tissues of the plant turpentine is simply a mobile juice, and that in the ordinary state of oleo-resin it is a product rather than a simple vegetable educt. It softens and liquifies when heated, readily takes fire in the air, and burns with a somewhat smoky flame. It is completely dissolved by alcohol or ether, and by distillation with water yields oil of turpentine.

Oil of turpentine ($C_{20}\,H_{16}$). As already indicated, this is obtained by distilling turpentine with water; it then forms the upper layer of the condensed product. For most purposes it is re-distilled with caustic alkali, acid matters and traces of resin being thereby removed.

Oil of turpentine is a colourless mobile liquid, of characteristic odour and hot pungent taste. It should be neutral to test-paper, of specific gravity 0·86, boiling-point about 320° Fahr., and a vapour density of 4·76. It rotates a ray of polarised light, to the left or right according to origin. It is very soluble in ether and absolute alcohol, less so in ordinary (hydrated) alcohol, and is not miscible with water. It is a good solvent of resins, oils, sulphur, phosphorus, and caoutchouc. Pure turpentine, as obtained by re-distillation in vacuo, has constant, well-defined, lævo-rotation. Berthelot distinguishes it as *terebenthen.*

Modifications and Derivatives of Oil of Turpentine. Under the influence of heat, or of chemical re-agents, or of both combined, oil of turpentine yields several interesting substances. *Isoterebenthen* is one of the products into which oil of turpentine is resolved on heating, in a closed vessel, to about 470° Fahr. It is a colourless liquid, having an odour of stale lemons, sp. gr. 0·843 at 71° Fahr., boiling-point 350° Fahr., possesses lævo-rotation of varying intensity on polarised light, yields a solid hydrate and hydrochlorate. *Metaterebenthen,* like isoterebenthen, has the same composition as oil of turpentine; it is formed under the same circumstances as isoterebenthen, but remains in the retort after the heat has been raised to 660° Fahr. It distils, however, at a temperature slightly higher than 660°, and then forms a yellowish, very viscid liquid of sp. gr. 0·913 at 68° Fahr. It has a disagreeable odour, and exerts lævo-rotation on polarised light.

When oil of turpentine is agitated with five per cent. of strong sulphuric acid, it becomes of a dark red colour, and viscid. On standing, the mass separates into two portions, and the upper clear liquid furnishes, on distillation, a body having the same boiling-point and composition as the original oil, but of an odour resembling that of oil of thyme: it is called *tereben.* *Colophen* is produced at the same time as tereben; its density, however, is twice as great, and its boiling-point is between 590° and 600° Fahr. It may also be obtained from colophony, hence its name. Neither tereben nor colophen has any action upon polarised light.

Water combines with oil of turpentine to form definite *hydrates,* of which three are solid and one liquid. When the oil is exposed to intense cold, crystals of *binhydrate* ($C_{20}H_{16}$, 2HO) sometimes separate, but generally a *hexahydrate* ($C_{20}H_{16}$, 6HO), called *terpin,* in large prismatic crystals, is deposited. The latter may be obtained in quantity by well mixing four parts of oil of turpentine, one of nitric acid (sp. gr. 1·36), and three of alcohol (sp. gr. 0·840), and setting aside for several weeks. When sublimed, the hexahydrate loses two equivalents of water, and is converted into a *quadhydrate* ($C_{20}H_{16}$, 4HO). The quadhydrate is also formed on exposing turpentine and water to a continued heat of about 120° Fahr. It is more soluble in hot than cold water, and is readily taken up by alcohol, ether, or benzole. A fourth hydrate, termed *terpinol* ($C_{20}H_{16}$, HO), which is a fluid at common temperatures, is formed on distilling either of the other hydrates with water containing a little hydrochloric or sulphuric acid. It has an odour like that of the hyacinth, boils at 334° Fahr., and is of sp. gr. 0·852.

Hydrochloric acid combines with oil of turpentine, and forms several liquid and solid bodies. The latter have very much the appearance and odour of camphor, and hence are termed *artificial camphors.* The *monohydrochlorate* ($C_{20}H_{16}$, HCl), called also *hydrochlorate of camphen,* or *of dadyl,* is best obtained by passing dry hydrochloric acid gas into artificially cooled oil of turpentine until absorption ceases. If the product be exposed to a freezing mixture of snow and salt, it soon becomes half filled with white prismatic crystals, having the characteristic aromatic smell and taste of camphor. They are insoluble in water, soluble in alcohol or ether, fuse at 239° Fahr., and boil at 329°, undergoing partial decomposition. The liquid portion of the above product is also a monohydrochlorate, having the same composition as the solid; it is termed hydrochlorate of pencyl, or of terebilen, inasmuch as that when distilled with quicklime it furnishes *pencyl* or *terebilen,* a liquid hydrocarbon isomeric with oil of turpentine, but possessing no rotatory power on polarised light. The solid hydrochlorate by similar treatment yields *camphen, camphilen,* or *dadyl,* also isomeric with oil of turpentine; boiling-point, 273° Fahr. A solid and liquid *bichlorhydrate of turpentine* ($C_{20}H_{16}$, 2HCl), *artificial lemon* or *citron camphor,* are formed when oil of turpentine or of lemons is placed in contact with excess of strong aqueous hydrochloric acid for several weeks. A liquid *subhydrochlorate* ($2C_{20}H_{16}$, HCl) has also been obtained. Hydrobromic and hydriodic acids form compounds with oil of turpentine somewhat resembling the hydrochlorates.

Chlorine attacks oil of turpentine, and yields a *quadrichlorinated* derivative ($C_{20}H_{12}Cl_4$). The latter furnishes a *bichlorinated* compound ($C_{20}H_{14}Cl_2$) on being heated. A *quadribrominated* oil ($C_{20}H_{12}Br_4$) has also been obtained. Tereben and chlorine give a colourless viscid liquid, termed *chlorotereben,* and artificial camphor and chlorine yield crystals of *chlorocamphen.*

Oil of turpentine is very susceptible of oxidation. The spontaneous production of resins from it has already been alluded to. By distillation with bichromate of potash and sulphuric acid it yields abundance of formic acid, and when gently heated with oxide of lead gives formic acid and *teretinic acid* ($C_{18}H_{14}O_{10}$). The latter crystallises in acicular tufts, and forms salts that, like itself, are insoluble in water but soluble in alcohol. A small quantity of oil of turpentine placed in a jar of oxygen gas standing over water and exposed to sunlight, rapidly absorbs the oxygen, and yields crystals of *hydrated oxide of turpentine* ($C_{20}H_{18}O_2$, 2HO), which are deposited on the sides of the vessel; it is soluble in alcohol, ether, and boiling-water. Strong nitric acid acts very violently upon oil of turpentine, the temperature frequently rising high enough to cause inflammation of the mixture. When diluted, however, nitric acid merely resinifies the oil, and produces, among other substances, terebic acid, which will presently be described in detail in connection with resin; *terephthalic acid* ($C_{16}H_6O_8$) isomeric with phthalic acid [NAPHTHALIC GROUP]; *terebenzic acid* ($C_{14}H_7O_4$?), fusible at 336° Fahr., and sublimable like benzoic acid; and *terechrysic acid* ($C_{12}H_6O_8$), of golden yellow colour, uncrystallisable, and very soluble in water.

The chief properties of the non-volatile or resinous constituents—the *resin*—of turpentine have already been described. [RESINS.] It now therefore remains only to notice the relations of the constituents individually, and shortly describe their derivatives.

Turpentine Resin, as a whole, is acid, and has the composition (HO, $C_{40}H_{29}O_3$). In reality, however, it contains three distinct acids isomeric with each other, but having dissimilar physical properties; their names are pimaric, sylvic, and pinic acids. The two latter are, no doubt, mere modifications of the first, and probably owe their dissimilarity to the action of heat. *Pimaric acid* is best obtained from the white resin or *galipot* of Bordeaux turpentine. The resin is powdered, digested in a mixture of six parts of cold alcohol and one of ether, which separates matters other than pimaric acid, and the residue is finally boiled with alcohol. On standing for a few days, the solution deposits crystalline tufts of the acid under consideration. It is very soluble in ether and hot alcohol, less so in cold alcohol. It fuses at 257° Fahr., but does not re-solidify till cooled down to 154° Fahr. The fused acid is clear and transparent as glass; when powdered it may be perfectly dissolved in its own weight of alcohol, but in a few minutes the solution begins to deposit elliptical crystals, which, like the non-fused acid, require ten times their weight of alcohol for solution. By distillation in vacuo pimaric acid furnishes sylvic acid, at first thought to be new, and called *pyromaric acid.* *Sylvic acid* may be obtained from powdered resin. The latter is well washed with cold alcohol to remove pinic acid, and the residue dissolved in boiling alcohol; on standing, the sylvic acid crystallises out. Its crystalline character is more pronounced than that of pimaric acid; in other respects the two much resemble each other. *Pinic acid,* or the amorphous resin of colophony, is obtained on evaporating the mother liquor from the preparation of sylvic acid; by heat it is partially decomposed, and changed to another isomer, *colopholic acid.*

By destructive distillation at a low temperature, turpentine resin yields the hydrocarbons *resinein* or colophen and tereben already referred to. At a higher heat it gives a liquid hydrocarbon containing *retinaphtha* or *toluen* ($C_{14}H_8$) [TOLUENIC GROUP]; *retinyl* ($C_{18}H_{12}$), isomeric with *cumen* [CUMINIC ACID]; and *retinol* ($C_{64}H_{32}$?), an inodorous and tasteless oil, of sp. gr. 0·9, and boiling-point about 460° Fahr. Retinol is a solvent of sulphur and iodine. It absorbs many times its volume of sulphurous and other gases, and is not acted upon by alkalies.

The acids of resin are monobasic, difficult to obtain in a definite crystalline state, are mostly insoluble in water, and soluble in ether. The alkaline resinates are of course true soaps, but are inferior in detergent qualities to the stearates, oleates, and margarates.

By prolonged ebullition with strong nitric acid, turpentine resin yields AZOMARIC ACID and *terebic* or *terebilic acid* ($C_{14}H_{10}O_8$). The latter is almost insoluble in cold water, moderately soluble in hot water, and readily taken up by alcohol or ether. Submitted to destructive distillation, it gives *pyroterebilic acid*, a colourless oily liquid of sp. gr. 1·01, and boiling-point 392° Fahr.

TURPENTINE, MANUFACTURE OF. The common turpentine used in the arts is mostly imported from America, in barrels and casks. [TURPENTINE.] It is used for very few purposes in the state in which it is imported. The process of distillation is in most cases resorted to, as a means of separating it into solid *resin* and liquid *oil* or *essence* of turpentine. Turpentine-works, where this distillation is carried on, are managed with much caution on account of the inflammable nature of the substance operated on. The viscid turpentine is put into a still and exposed to heat; it melts into a liquid, gives off its essential or oily portion in the form of a vapour, and there remains a liquid resin in the still. The vapour, on leaving the still, passes through a refrigerator or cooling vessel, and is collected as a clear and limpid oil or spirit of turpentine. The residue is taken from the still as *resin*, *black* or *yellow* according to the kind of turpentine which has been employed.

A patent was taken out in America a few years ago, for making soap at the same time as distilling turpentine. Raw turpentine and alkali were put into the still; the spirit of turpentine passed off into a condenser, while the resin became partially saponified by combining with the alkali, and prepared to enter into the composition of soap.

Considered as an ingredient in house-painters' colours, spirit of turpentine, or *turps*, is an important substance. Chevreuil has pointed out three kinds of service which turpentine renders to oil-colours. It facilitates the application, by diminishing the viscidity of the oily mixture; it allows the painter greatly to modify the appearance of his work, by varying the degree of gloss or of dullness; and it prevents the appearance of cracks which would otherwise be visible when the work is varnished. As, however, the durability of the work depends chiefly on the oil, the best mode is found to be to use as little turpentine as possible when the work is neither to be dead nor varnished.

Common or crude turpentine is imported to the extent of about a quarter of a million cwts. annually (246,458 cwts. in 1858, and 256,663 in 1859). A small import duty, imposed many years ago, has been since repealed.

TURPENTINES, *Medical Uses of.* Common turpentine, or Resina liquida (*Terebinthina vulgaris*), as the natural combination is termed, yields two distinct articles to the Materia Medica, namely,—1. Oleum terebinthinæ, obtained by the distillation of the liquid resin; 2. Resina, or simply resin or rosin, which is resin with a little water, remaining after nearly all the oil has been distilled off: but if the process of distillation be carried as far as possible without causing new combinations of the elements, all the water is driven off, and the residuum becomes black, and is termed colophony, and sometimes fiddler's rosin. The resin is used merely to make cerates, ointments, and plasters, which are more or less stimulant.

As turpentines have a very disagreeable taste, it is customary to form them into pills or boluses; but since this is rather difficult, it is well to be aware that magnesia affords a convenient means of accomplishing it, as in the case of the oleo-resin of copaiba. The kind of magnesia and the quantity to be used vary in the different kinds of turpentine. Bordeaux turpentine (from *P. maritima*, or *P. pinaster*) requires one twenty-one part of magnesia usta to form a pill-mass. Venice turpentine (from *Larix Europæa*), called also turpentine of Briançon, requires a quantity equal to its own weight of carbonate of magnesia to form a pill-mass. But the quantity of magnesia must vary with the age of the turpentine, more being required when it is very fresh than when the turpentine is old and more solid. The durability of the mass also varies with the proportion of magnesia used.

One ounce of Venice turpentine united with one ounce of hydrated carbonate of magnesia formed a mass which was slow of consolidating, and the pills soon lost their globular form: but three ounces of the magnesia formed a persistent mass. One ounce of turpentine and one ounce of Bordeaux turpentine, with six drachms one scruple of carbonate of magnesia, furnished a slowly hardening mass, which at last resolved itself into powder; while one ounce of the same turpentine with eight grains of magnesia formed a soft mass, which, after thirty-six hours, was sufficiently consistent to form pills. Some days afterwards it became harder, and did not for a long space become friable. With a yet smaller quantity of magnesia these changes take place more slowly, so that it is requisite in magistral formulæ never to order less magnesia than the one-fiftieth part of the turpentine. This proportion forms in a few minutes a transparent pill-mass with a vitreous fracture. But the finer sorts of turpentine may be administered in the liquid form; the coarser must be in pills.

Oleum Terebinthinæ, Oil or Spirits of Turpentine, as it occurs in commerce is never pure, but contains more or less resin formed by the action of the air; and to obtain it pure, it is ordered to be distilled a second time, and then called Oleum Terebenthinæ purificatum, and sometimes Oleum Pini purissimum. The commercial oil of turpentine has an acid reaction, the purified has not.

Oil of turpentine is one of the most energetic of the volatile oils: the vapour is quickly destructive to plants, and in large doses it acts as a poison to both vertebrate and invertebrate animals. Like all volatile oils it acts powerfully on insects which respire by the whole surface, hence it instantly kills wasps, lice, fleas, and worms. It has a more potent action on the lower animals than on man, both externally and internally. Applied to the skin of horses, it blisters it more rapidly than the skin of man; and two drachms administered to a dog (Schubart, in Christison) caused death in three minutes, while human beings have taken three ounces without any serious consequences. Indeed Dr. Christison states that he is not aware that it has ever proved fatal. Horses also have taken for some days as much as ten or twelve ounces.

In moderate doses it acts as a stimulant to the stomach and whole intestinal canal; manifested by a grateful feeling of warmth, with greater activity in the mucous membrane of the intestines, and of the liver. The increasing secretions of these organs, particularly of the bile, causes more frequent evacuations; further, it promotes the secretion of the kidneys, and likewise, but less evidently, of the skin, the pulmonary surface, and also of the uterus. It communicates the terebinthaceous odour to the cutaneous perspiration, and sometimes even causes an eruption on the skin.

Its effect on the vascular system is equally stimulant: Dr. Copland made many experiments on himself, when in health, and found that his pulse became more frequent, small, and contracted; with feelings of intoxication, anxiety, shiverings, a sensation as if the intestines were drawn towards the vertebral column, unpleasant eructations, thirst, and a sharp hunger; sensations which food caused gradually to subside, without vomiting or diarrhœa. Very large doses often produce temporary intoxication, and sometimes a kind of trance, lasting twenty-four hours, without any subsequent bad effect.

Implicit reliance is placed on oil of turpentine against the tape-worm. It is in general recommended to be given in large frequently-repeated doses, mixed with mucilage, syrup, and cinnamon-water, and is thought to directly kill the worm, rather than destroy it by removing the means of its further nourishment. But this mode of administration is by no means so eligible as that of small doses (ʒj to ʒij) per diem for a continuance, a plan recommended by Vogt ('Pharmacodyn.,' vol. ii., p. 163), and proved by Dr. Graves to be effectual. "Turpentine is of value in leading to the expulsion of flukes (distomahepaticum [WORMS; also BOTRYLLIDÆ, in NAT. HIST. DIV.] of sheep, or the rot), and is one of our most valuable anthelmintics." Professor Simonds' Report to the Royal Veterinary College, Dec. 14, 1860.

In chronic affections of the liver, obstructions from gall-stones, &c., if no inflammatory state be present or approaching, oil of turpentine with twice its weight of spirit. æther. sulphur. in the dose of from 10 to 20 drops, in yolk of egg, is often very useful; in melæna and obstructions of the liver, and vena porta, &c. It is most likely, from its action on the liver, that it proves serviceable in chronic rheumatism. In sciatica, Dr. Cheyne recommends it in small doses. It is useful in atony of the intestines, lacteals, particularly of old and phlegmatic people, especially of the lower orders. Even typhus fever, if there be a tympanitic state of the abdomen, is benefited by it, and Dr. Chapman has found it valuable in the yellow fever of Philadelphia. Dose from 1 to 2 drachms per diem. In cholera asiatica, with spirits of ammonia. In obstinate constipation, in large doses. In scarlet fever, when the eruption does not come freely out, 10 to 60 drops in one to three tea-spoonsful of castor-oil. (Dr. Delany, of Georgia, U.S.) In chronic cramps, convulsions, and epilepsy (with only temporary benefit). In atony of the kidneys and bladder. In catarrhus vesicæ, gleet, gonorrhœa, and leucorrhœa, it may often be advantageously substituted for copaiba. In atonic hæmorrhages it is very useful. In puerperal peritonitis, applied externally, it is of great utility. Externally in burns, the linimentum terebinthinæ, or hot dressing, is useful. In peritonitis with a tympanitic condition of the abdomen it is very excellent. The vapour of oil of turpentine can be used as an anæsthetic, and as a substitute for chloroform.

Chian or *Cyprus Turpentine*, called also true turpentine, is obtained from the *Pistachia terebinthus*, a native of Barbary, Syria, the south of France, and, above all, of the Grecian Archipelago. Eight or ten ounces are the utmost obtained from one tree; hence it is very dear. It is of the consistence of new honey, tenacious, pellucid, of a light yellowish-green colour. The odour is penetrating and peculiar. It has a slightly bitter taste; but when adulterated with any of the coniferous kinds, its odour is strong, its taste acrid, and of a sensible degree of bitterness. It consists of a volatile oil and resin, and when by time the former is dissipated or oxidised, it becomes hard and translucent.

This article is scarce in a pure state, it being mixed largely with Venice turpentine, and indeed in many instances altogether supplanted by that article. It was greatly esteemed by Hippocrates; and in the present day is chewed by the inhabitants of Turkey, Persia, &c., as mastic is, to sweeten the breath. But it likewise improves the digestion, having a very beneficial influence on the secretions of relaxed mucous membranes. Hence it is useful in chronic catarrh, both of the lungs and genito-urinary organs. For the latter it is advantageously combined with sulphate of zinc.

TURPETH MINERAL. [Mercury. *Bisulphate of mercury.*]

TUSCAN ORDER. [Column; Roman Architecture.]

TUSCAN SCHOOL OF PAINTING. [Painting.]

TUSSILAGO FARFARA (Coltsfoot), a perennial plant belonging to the order of compound plants, common in damp, clayey fields, road-sides, and the banks of rivers, the yellow flowers of which are seen in spring preceding the nearly heart-shaped, smooth-toothed leaves, which, from their resemblance to a young horse's hoof, have received the popular name of coltsfoot. The whole plant is nearly devoid of odour. The root has a styptic bitter taste; the leaves and flowers are bitter and mucilaginous. The chief constituents are mucilage, bitter extractive, tannic acid, colouring-matter, salts, and woody fibre. The watery infusion becomes of a dark green and turbid appearance on the addition of a solution of sesquichloride of iron. Its properties may easily be inferred from the above statement; they are demulcent, slightly astringent, tonic, and expectorant. Its name both in Greek (*βηχιον*) and in Latin proves the estimation in which it was held as a means of relieving cough—a reputation which it does not maintain in modern times among professional observers, except a very few; but with the vulgar it is still in great esteem. The young leaves make a wholesome salad in early spring. The ancients smoked it rather than used it in any other form; and in the north of Europe, and even with our own vulgar, this mode is employed, what is sold under the name of British Herb Tobacco being chiefly coltsfoot. This at least is harmless; not so the nostrum called Essence of Coltsfoot, which is a combination of balsam of tolu, compound tincture of benzoin, with a large quantity of rectified spirit of wine, and not a particle of the substance from which it takes its name. In chronic coughs accompanied by much local or general irritation, still more in genuine tubercular consumption, such heating ingredients must be very hurtful; though a plain decoction of real coltsfoot would be unobjectionable, and might be beneficial. The leaves of coltsfoot form, when moistened with warm water, an excellent emollient poultice.

TUTANIA. [Britannia Metal.]

TUTELA. [Tutor.]

TUTENAG, an alloy used in China in the manufacture of the *gong*. It is white, resembling silver in appearance, and is very sonorous when struck. Its specific gravity was found by Dr. Fyfe to be 8·432; it is susceptible of a fine polish, and does not readily tarnish; at common temperatures, and even at a red heat, it is malleable, but when heated to whiteness it is rendered brittle.

It has been analysed by Dr. Fyfe, who found it to consist of—

Copper	40·4
Zinc	25·4
Nickel	31·6
Iron	2·6
	100·

It may therefore be regarded as a kind of German silver.

TUTOR. By the Roman law a male under the age of fourteen, and a female under the age of twelve, were called Impuberes. A male who was impubes was incapable of doing any legal act by which he might be injured; his property was under the care of a tutor, who was so called from his office of defending or protecting (tuendo) the impubes in the transactions which were necessary for the administration of his property. The office of the tutor was tutela; and the impubes, who with respect to his tutor was called pupillus, was said to be in tutela, in tutelage. The tutor's business was to manage the property of his pupillus, and to add to his acts the legal sanction (auctoritas). The tutor's office as tutor was confined to the property of his pupillus, who, as to his person, was under the care (custodia) of his mother, if he had one; if not, we must suppose that the tutor would sometimes have the care of his person also. When the pupillus attained the age of puberty, he had the capacity of contracting marriage, and of doing other legal acts, and was freed from the control of his tutor. But though the law gave full legal capacity to the pupillus on his attaining puberty, it still gave him some further protection until he was twenty-five years of age. [Curator.]

A father could appoint by testament a tutor for his male children who were impuberes and in his power: he could also appoint a tutor for females who were in his power, even if they had attained puberty. He could also appoint a tutor for the wife of a son, who was in his power, and for his grandchildren, unless by his death they should come into the power of their father. A man could also appoint a tutor for his wife, who was in manu, for she stood to him in the legal relation of a daughter; and he could also give her the power of choosing a tutor. The origin of this testamentary power was probably immemorial custom, which was confirmed by the Twelve Tables. Tutors thus appointed were called dativi: those who were chosen by a wife under a power given by the husband were tutores optivi. If a testator appointed no tutor, the tutela was given to the nearest agnati by the Twelve Tables: such tutores were legitimi. If there were no agnati, the tutela belonged to the Gentiles so long as that part of the law (Jus Gentilitium) remained in force. When there was no person appointed tutor, and no legitimus tutor existed, a tutor was appointed for persons at Rome under the provisions of a Lex Atilia, and for persons in the provinces under the provisions of a Lex Julia et Titia.

Though a pupillus could not do any legal act which should be to his injury, he could enter into contracts which were for his benefit. The tutor's office was defined to consist in doing the necessary acts for the pupillus, and interposing or adding the legal authority to his proper acts (negotia gerere et auctoritatem interponere: Ulpiani, 'Frag.,' tit. xi., s. 25). The doing of the necessary acts applied to the case of the pupillus being infans, that is, under seven years of age, absent, or lunatic (furiosus). When the pupillus ceased to be infans, he could do many acts himself, and the auctoritas of the tutor was only necessary to make them legal acts.

A tutor might be removed from his office if he misconducted himself in it. The pupillus had also an action against him for mismanagement of his property. The tutor was allowed all proper costs and expenses incurred by him in the management of the affairs of the pupillus; and he could recover them by action. Security was required by the prætor from a tutor for the due management of the affairs of a pupillus. unless he was a testamentary tutor, for such tutor was chosen by the testator, and, generally, unless he was appointed by a magistratus, for in such case he had been selected as a proper person.

The tutela of women who were puberes was a peculiar Roman institution, founded on the maxim that a woman could do nothing without the auctoritas of a tutor. But there was this difference between the tutela of pupilli and of women who were puberes: in the case of pupilli the tutor both did the necessary acts, particularly when the pupillus was infans, and gave his auctoritas; in the case of women who were puberes, the tutor only gave his auctoritas.

The Vestal virgins, in virtue of their office, were exempted from tutela. Both libertinæ and ingenuæ were exempted from it by acquiring the Jus Liberorum, which was conferred by the Lex Julia et Papia Poppæa on women who had a certain number of children. The tutela of a woman was terminated on her marriage, by which she came in manum viri; and also by other means.

A woman had no right of action against her tutor as such, for he did not do any act in the administration of her property; he only gave to her acts their legal validity by his auctoritas.

TUTTY. [Zinc.]

TWELVE TABLES. The Roman writers speak of the Twelve Tables under various names: they call them Leges Decemvirales, Leges XII. Tabularum, sometimes simply Lex, the Law, as being pre-eminently the foundation of Roman Law; and by other names. After some struggle between the patricians and the plebs, the story runs that a plebiscitum was passed (B.C. 454) with the assent of the senate, in pursuance of which three commissioners were sent to Athens and other Greek states to inquire about their legislation, that the commissioners returned in B.C. 452, and that in the following year ten patricians (Decemviri) were appointed to draw up a code of laws, whence the name Leges Decemvirales. The Decemviri, at the head of whom was Appius Claudius, formed a code of Ten Tables, which were approved by the senate, and received the final sanction of the Comitia Curiata. The code being considered defective, Decemviri were again elected (B.C. 450), and two more tables were added, whence the name Twelve Tables. The laws were cut on tablets of bronze and set up in a public place: they were not promulgated till B.C. 449, after the overthrow of the Decemviri, who had attempted to perpetuate their power against the terms of their appointment.

It is impossible to ascertain from the scanty history of the Decemviral legislation how far the story of this mission to Greece is true. It is very doubtful whether the codes of the Greeks at all affected this the first Roman attempt to form a system of law, but it may safely be assumed that the basis of the Decemviral code rested on the customary law of the Romans, and that except in those few general features in which all early codes of law bear resemblance to one another, the Roman Decemviral code is one and distinct. It is said that the Twelve Tables perished in the destruction of the city by the Gauls, but there appears to have been no difficulty in reconstructing the tables. No Roman writer suggests any doubt of their genuineness.

The Twelve Tables are called by Livy (iii. 34), "Fons publici privatique juris"—the source of Public and Private Law,—according to a division of the matter of law which was familiar to the Romans. That part which concerned the Jus Publicum, which bears some analogy to our term constitutional law, was changed in the course of time; but the Jus Privatum, which determined the rights and duties of the citizens, was never formally repealed, and only so far modified as it was affected by the changes in circumstances by which some of the laws of the Twelve Tables fell into desuetude, and by the gradual growth of the Jus Prætorium. In course of time the language of the tables became obscure, and this, with the great change of circumstances, must have rendered many of their provisions inapplicable. In the later times of the republic, Cicero observes that since his boyhood the practice of learning the Twelve Tables had been superseded by the growing importance of the Edict.

The Roman jurists made commentaries on the Twelve Tables. Six books of a commentary by Gaius are mentioned, which shows that at least as late as the time of Antoninus Pius the decemviral law was in substance still in force, that is, that the fundamental principles of Roman law (the Jus Privatum) were still to be sought in the then antiquated language of the Decemviri.

Much has been written on the subject of the Twelve Tables. The last and most complete history of the labours of modern critics on the Twelve Tables is by Dirksen, in his 'Uebersicht der bisherigen Versuche zur Kritik und Herstellung des Textes der Zwölf-tafel Fragmente,' Leipzig, 1824. The fragments of the Twelve Tables appear in the several parts of the work, and are also collected at the end.

For an excellent dissertation upon the Twelve Tables as illustrative of the archaic form of the Latin language, the reader is referred to an able article in the late Dr. Donaldson's 'Varronianus.'

TWILIGHT, the name given to the light which remains after the sun has set, or which is seen immediately before it rises. The reason of this appearance is explained in SUN (col. 915), being the effect of the light which is reflected from the higher strata of the atmosphere, in a manner which will be understood from the diagram in the column cited.

In our latitudes, at the summer solstice, a portion of the twilight continues from the setting of the sun to its rising, circling, as the hours of night and morning proceed, from the western horizon through the north, to the east; which is the cause of there being scarcely any true night at that period of the year.

J. H. Lambert endeavoured to distinguish, besides the primary twilight, a secondary and even a ternary twilight, both the latter being caused by the successive reflection, by the clouds and the air, of light already reflected from other regions of the atmosphere, their clouds, &c. In conformity with these views, Sir John F. W. Herschel has attributed to such a cause the phenomenon, seen in the clear atmosphere of the Nubian deserts, which has been described by travellers under the name of the "after-glow." To a corresponding cause must be ascribed the rose-coloured illumination of the summits of high mountains after sunset (often witnessed of those of Mont Blanc and Monte Rosa), but in these cases the reflected light is coloured by its traversing tracts of the air of which the vapour is in an opalescent state, imparting to it various hues of red and orange. [VAPOUR.]

The astronomer last named, always careful to explain the physical processes which are operative in the production of astronomical phenomena, in addition to the mathematical principles on which they depend, has pointed out that a portion of the light of the sun and moon reaches us after they are set, by means of the atmosphere, "by *reflection* upon [and from] the vapours and minute solid particles which float in it, and, perhaps, also on the actual material atoms of the air itself." (See 'Outlines of Astronomy.' ed. 1858, par. 44, 45.)

The observations which have been made during the last two or three total solar eclipses are very instructive, in two respects, concerning the light ordinarily received by the earth, including that of twilight. The character of the darkness, while the totality continues, so much more intense than that of night caused by the mere aversion of the hemisphere from the sun, evinces how intrinsically dependent upon that luminary for light the earth really is; while the amount and peculiarity of the illumination actually existing at the same time, shows in how great a degree we are indebted to the reflective and refractive powers of the atmosphere, and to the reflection by the floating particles alluded to, by aqueous vapour becoming visible but not yet cloud, by the clouds themselves, and by the earth, reciprocally and unitedly, for the light we enjoy after the commencement and during the progress of that aversion.

But all this is, of course, affected by the degree of transparency of the atmosphere and its difference at different altitudes, the less transparent, in the mass, so far as we know, being those nearest the earth; while there are facts which indicate that air perfectly free from aqueous vapour, such as we must conclude it to be above a certain height, is less transparent, or more absorptive of light, than the mingled atmosphere of air and aqueous vapour incumbent on the earth's surface, when the temperature is such as to sustain the latter in a perfectly gaseous condition. When the sky is thus free from visible vapour and cloud, however, the transparency of the atmosphere is almost invariable, as Professor Seidel has shown.

Another consideration affecting this subject relates to the probable nature of the highest regions of the atmosphere, on which the amount of reflected light causative of twilight must be greatly dependent. If, as inferred by Graham and Poisson [SURFACE OF THE EARTH, col. 982], the terminal stratum be solid—air-ice—the reflection from its inferior surface, and from the inferior surfaces of the comparatively dense strata immediately below it, must be more powerful than that from the rare, purely aëriform strata (of which alone the highest regions are commonly supposed to consist), and hence may exert a marked effect in prolonging the twilight, as well as in lessening the darkness during the entire time when the sun is below the horizon. It may be that this reflection is the principal agent in producing the remarkable amount of light still remaining during a total eclipse of the sun, as noticed above. What may be the bearing upon this subject of the observed polarising power of the sky during such eclipses has not been investigated, though the materials for such an inquiry, we believe, have been obtained, especially from the eclipse of July 18th, 1860. It seems probable that the polariscope would furnish the means of determining whether such reflection does in reality take place, and also, if taken in conjunction with the atmospheric refraction of the heavenly bodies, of determining what the structure and constitution of the upper regions of the atmosphere really are.

Intimately connected with this particular subject is the application of the phenomena of twilight, or rather of the amount of depression of the sun at the close of twilight, to determine the height of the atmosphere, first proposed by Kepler, and which, in fact, gives a height nearly agreeing with that inferred from the law of elasticity of the air, of between forty and forty-five miles. But the argument from the observed depression of the sun is inconclusive, because we do not know when twilight has ceased, nor, indeed, whether it ever ceases. According to Leslie, admitting, from the fact that in clear weather in no climate is there total darkness, even at midnight, "that the body of air extends to such an altitude, as to receive the most dilute glimmer, after the sun has attained his utmost obliquity, and sunk ninety degrees below the horizon," the elevation of the atmosphere must be equal at least to 1638 miles. In this reasoning, however, no account is taken of the necessary limitation of the atmosphere by the cold of interplanetary space, which must have effect at a point greatly nearer the earth. On the other hand, the actual demonstration of the existence of a solid or liquid stratum at the summit of the atmosphere, by the means suggested above, would probably involve also, the determination of its altitude, and, conversely would enable us to fix, definitively, the extent of twilight upon the earth's surface. [ATMOSPHERE; METEOROLOGY.]

A question here arises as to the photographic intensity and properties of the reflected light from which the phenomenon of twilight proceeds, as compared with those of the direct sun-light itself. But this comparison does not appear to have been made in any express manner. According to the photo-chemical researches of Bunsen and Roscoe ('Phil. Trans.' 1859, p. 898), the chemical illumination, that is, the affection by the chemical rays, of the earth's surface, is merely a function of the sun's zenith-distance; all the elements of the sun's radiation (so to call them), light, heat, and chemical action, diminishing equally with his altitude. As the diffused light of day is all, in its immediate origin, reflected, and as it, in common with that reflected from the clouds, possesses normal chemical action, differing only in its intensity from that of the direct light of the sun, we may infer that a similar difference only exists in the case of twilight.

TWINKLING OF STARS, or SCINTILLATION (*scintilla*, "a spark of fire"). This term is applied to a phenomenon which has attracted the attention of astronomers and scientific men in all ages. It consists in rapid variations in the brightness of a fixed star when observed with the naked eye, and is often accompanied by changes in the colour, and alterations in the apparent diameter of the star or in the length of the diverging rays which appear to dart from its centre in different directions. It is commonly stated that the twinkling disappears when the star is viewed through a telescope; such, however, is not the case, although under such circumstances the phenomena are modified.

This subject occupied but a very small space in scientific works, if indeed it was to be found at all in them, until M. Arago devoted one of his searching scientific notices to the subject in the 'Annuaire pour l'An 1852, publié par le Bureau des Longitudes;' nevertheless the importance of the subject has never been forgotten, and Kepler even invited scientific men to a conference on the subject, and appointed Frankfort as the place of rendezvous.

The changes in colour which accompany scintillation, and form one of its most important features, were noticed by early observers. Indeed the name given by the Arabs to Sirius refers to this fact; they call it *barakesch*, or "the thousand-coloured star." Tycho, writing in 1572, respecting the new star of that year, compares it to the reflections of a cut diamond moving in the presence of light. Kepler also refers to the Dog Star as presenting by turns all the colours of the rainbow. Hooke, in his 'Micrographia,' refers to the various colours which accompany the scintillation of stars, appearing red at one moment, yellow at another, and blue at a third. Forster ('Phil. Mag.,' 1824) remarks that sometimes the intensely red light appears after two dilatations of the star, under other circumstances after three, but often without any apparently regular law. Several observers notice the scintillation of the planets; but no astronomer refers to their change of colour. Scintillation in their case is a simple change in the intensity of the light.

The scintillation of a star, when viewed through a telescope, was first described by Simon Marius, who recommends that the eyepiece be removed from the telescope, and the eye be substituted for it, at a time when the sky is very clear and the air tranquil. The scintillation will then appear like a fulmination or ebullition of the substance of the star, and certain determinate and distinct colours will appear in greater or less abundance according to the stars observed. Thus

Sirius presents green, yellow, red, and blue repeatedly following in the same order. Nicholson also in 1813 remarks that the circular disc of a star vacillates in such a manner as to give the idea of a number of discs passing in succession before each other. These discs are of different colours: the light appeared to come from different sides, and the most frequent colours were blue, steel-blue, pea-green, brilliant copper, red, and white. The same observer viewing Sirius through an achromatic by Ramsden, magnifying twenty-four times, and the eye-piece adjusted for distinct vision, the observer struck lightly on the tube a series of rapid blows with his fingers, so as to make the image of the star describe a luminous line, every part of which displayed the most lively colours, and it was calculated that the light of Sirius changed in colour before arriving at the eye at least thirty times in a second.

Scintillation presents phenomena too remarkable to have been allowed to remain without attempts, at least, at explanation. Aristotle, who noticed the scintillation of the fixed stars, and the steady light of the planets, speaks of a want of fixity in our sight for such distant objects, while the planets being comparatively near can be viewed with a steadier gaze. Ptolemy also refers to the trepidation of the organs of sight, and the consequent trembling of the heavenly body. Alhazen and Vitellion refer the twinkling of stars to the effects of refraction which the stellar rays experience in our atmosphere. Aguillonius explains it by the rapid movement of rotation of the stars. Tycho adopts such an explanation as when a diamond cut into facets rotates, but the planets do not scintillate because he imagined them not to rotate. Cardan adopts Aristotle's explanation. Scaliger, among other attempts at explanation, refers to the intermittent light of an incandescent body, and to the changes in the intensities of the stellar light produced by vapours floating in the atmosphere. Galileo's explanation assumes a vibration which stars impress upon their own light. Kepler compares the stars to diamonds cut into facets so that the least movement produces iridescent colours, or in other words he supposed a star to contain angular surfaces unequally luminous. Scheiner imagines scintillation to be an optical illusion. Descartes explains the phenomenon by means of his favourite vortices or tourbillons, which he supposed to surround all celestial bodies. Huyghens explains scintillation by means of the vapours of the earth; and Gassendi attributes it to a vibratory motion in the eye. Riccioli calls in the aid of atmospheric vapours, and imagines also that particles of dust and opaque filaments floating in the air influence the phenomenon. Hooke explains it by the irregular refractions of the stellar rays in our atmosphere, arising from the unequal distribution of heat. Sir Isaac Newton refers to the refractive power of the humours of the eye, and also of the atmosphere, and speaks of a trembling movement in the latter. Jurin endeavours to explain scintillation by means of Newton's theory of fits of easy transmission and reflection. Cassini explains it by supposing a sort of luminous coma to surround the stars, and to undergo refraction and reflection in our atmosphere, but that these scattered rays being united through the intervention of a telescope the twinkling is less apparent. Long explains twinkling as the momentary disappearance of the stars, in consequence of the interposition of motes floating in the air. Mairan refers it to an undulatory movement like that of the horizon seen over a vast plain illuminated by the sun. Michell's explanation is based on the corpuscular theory of light. Lalande refers to the agitation of the air, and to motes floating in it, forgetting, as Long had done, that these motes must be at least equal to the diameter of the pupil of the eye. Muschenbroeck refers to the vivacity of light and to the activity with which it acts on our organ of sight. Darwin explains twinkling by means of the theory of accidental colours which was much discussed in his day, and explains it by the law of contrast. Saussure speaks of the oscillation of the luminous rays produced by the alternate condensations and dilatations of certain parts of the atmosphere. Dr. Thomas Young says,—"The cause of the twinkling of the stars is not fully ascertained, but it is referred, with some probability, to changes which are perpetually taking place in the atmosphere, and which affect its refractive density. It is said that in some climates, where the air is remarkably serene, the stars have scarcely any appearance of twinkling." Arago remarks on the singularity of the fact, that the author of the doctrine of interference of light, and indeed "of the only really new experiment which has been made on scintillation from the time of Aristotle to our own day, should not hesitate in facing the difficulties of the problem to say, 'I do not know.' There is more true merit in this candour than in the former unsatisfactory attempts at explanation." Nicholson, however, was equally candid, for he professed his inability to find in any of the known properties of light the cause of the phenomena of twinkling. Biot in his 'Astronomie' bases his explanation on the unequal refraction of the rays by our atmosphere. Forster imagines that the changes in colour which accompany twinkling must be due to some change in the star itself, or that our atmosphere acts like a prism on the rays of light. Capocci refers the phenomena to our eye and not to any changes in the star, while Kümtz, in his 'Meteorologie,' refers to a supposed oscillation of the star as a mere point of light about its mean position, while a planet having an apparent diameter of from 30 to 40 seconds, it is more difficult to appreciate its apparent change in volume.

Lastly we come to the explanation of Arago himself. That keen observer was very much struck with the experiment of Nicholson, who observed Sirius through a telescope, and caused the image to vibrate by tapping on the tube, when it appeared like a coloured luminous ribbon. On applying this experiment to other stars the coloured ribbon was observed with stars up to the sixth magnitude, but no trace of colour was observed with a star of the seventh. Another method of studying scintillation is to direct an achromatic telescope towards a brilliant star and then to move the eyepiece out of focus. The image then becomes an irregular disc approaching a circular form, and of a diameter greater or less according to the position of the eye-piece. The disc oscillates as though a number of discs of different colours were in motion. A third method of observing scintillation through a telescope is to contract the aperture by means of an opaque screen with a hole in the centre placed before the object-glass. On viewing the image of a star out of the focus, and consequently enlarged, its centre will appear to be pierced with a dark but regular hole. The opaque screen used by M. Arago had a central opening of only three or four centimètres in diameter; the image of a star at the focus was round and precise, but surrounded with a series of light and dark rings perfectly well defined. The lustre of these rings constantly varied in different parts of their contour, often disappearing, at certain points entirely. Under these circumstances, if the eye-piece were gradually pushed inwards, the image of the star would gradually dilate, and a well-defined black spot would appear in the centre. A further motion of the eye-piece inwards caused the dark spot to dilate into a small luminous disc, occupying the centre, surrounded by a dark ring, and this by a larger luminous ring. Or in a third position of the eye-piece, still nearer to the object-glass, the centre of the image is obscure, but surrounded by a large brilliant ring, succeeded by a dark ring, and this again surrounded by a luminous ring.

All these phenomena plainly refer the phenomena of scintillation to the interference of light. [INTERFERENCE.] Luminous rays proceeding from a point, such as a fixed star, and passing through our atmosphere, subject as it is to great variations in heat, moisture, and density, must have very unequal velocities; if such rays be brought to a focus by means of a lens, as they are by the lens of the eye, the effect of their reaching us with different velocities will be seen by the alternate brightening and darkening of the image in such focus, by the known laws of interference. If, however, the rays proceed not from a point, but from a disc, such as a planet, the effects would so far disturb each other as to prevent their being observed, or if observed, but imperfectly. M. Arago has contrived three methods, or instruments (*scintillometers*, as he calls them), based upon the change of the central spot from dark to light, which occurs the more frequently in proportion as the scintillation is strong; for example, in preparing a telescope as a scintillometer as above directed, with a pierced screen before the object-glass, on directing it to the stars named in the first column of the following table, at the heights above the horizon indicated in the second column, the central point became luminous, in the course of five minutes, the number of times mentioned in the third column:—

January 14, 1851.

Sirius	20°	40
Rigel	31°	17
Aldebaran	57°	13
La Chèvre	81°	8

By observations of this kind M. Arago thinks it possible to decide what are the climates, the seasons, the elevations, and other circumstances, under which scintillation entirely disappears.

While writing this article, we have received from M. Andrès Poey, Director of the Physico-Meteorological Observatory of Havannah, a Memoir entitled 'Loi de la Coloration et de la Décoloration des Etoiles, du Soleil, et des Planètes,' reprinted from the 'Annuaire' of the Meteorological Society of France, vol. viii., 1861. Our space will not allow us to do more than point out one remarkable result obtained by M. Poey, namely, that when, in viewing a fixed star through a telescope, the eye-piece is drawn out the series of rings obtained are complementary in colour to those seen when the eye-piece is pushed in towards the object-glass.

TYCHE, in the Greek mythology, one of the goddesses of Destiny: with the Romans FORTUNA was nearly the correspondent deity, but uniting in herself the attributes of the Greek goddesses of destiny was on the whole of a somewhat sterner character. Tyche was the daughter of Zeus the liberator. She was the guider of the affairs of the world, the bestower of good fortune, the impersonation of chance, uncertainty, and transitoriness. In art, on gems, coins, &c., she is frequently represented with attributes indicative of one or other of those qualities; with the rudder as providence; the wheel or ball as chance and uncertainty; with the horn of plenty, or with a patera in the right hand, and ears of wheat and poppies in the left, as the bestower of gifts; as the good-fortune of cities she is figured as a richly draped female with a crown of towers, a cornucopia and other attributes of prosperity. Tyche had temples devoted to her worship at Smyrna, at Pharae in Messania, at Ægiria in Achaia, at Thebes, and elsewhere. (Zoega, 'Tyche und Nemesis;' Müller, 'Archäol. der Kunst,' and 'Denkmüler der Alten Kunst.')

TYPE-FOUNDING. [PRINTING.]

TYPE METAL. The alloy formerly used for printers' types consisted of lead and antimony in about the following proportions :—

Lead	75
Antimony	25
	100

Recently, however, a harder description of metal has been found necessary, especially for the smaller letters, and the necessary quality has been attained by the partial or even total substitution of tin for lead in the above compound. The alloy of this description most commonly used is the following :—

Lead	50
Tin	25
Antimony	25
	100

Another alloy known as Didot's metal consists of—

Lead	30
Tin	30
Antimony	30
Copper	10
	100

The latter alloy, although very hard, appears to be too brittle for the purposes of the printer.

TYPES. [ORGANIC CHEMISTRY, *Constitution of organic compounds.*]

TYPHOON. [WIND.]

TYPHUS. [FEVER, CONTINUED.]

TYRANT. The words tyrant and tyranny come respectively from the Greek *tyrannos, tyrannis* (*τύραννος, τυραννίς*), through the Latin. The earliest instance of the word tyrannus is perhaps in the Homeric hymn to Ares (Mars). It is used by the earliest extant Greek historians, Herodotus and Thucydides, to signify a person who possessed sovereign power and owed it to usurpation, or who derived it from a person who had obtained such power by usurpation, and who maintained it by force. A familiar example of a tyrant is Pisistratus, who usurped the supreme power at Athens B.C. 560, and was succeeded in it by his eldest son Hippias. A Greek tyrant who obtained sovereign power was a monarch in the proper sense of that term. [MONARCH.] If he acquired a power which was somewhat less than sovereign, he was not a monarch; but in either case he would perhaps be called tyrannus; and accordingly the word does not express with accuracy the degree of political power which an individual acquired, but it rather expresses the mode of acquisition, or refers to its originally illegal origin. Still the term tyrant, as used among the Greeks, always indicates that the person so called was at the head of the state, and possessed at least more power than any other individual or any number of individuals in it. The word, as used by the older Greek writers, did not carry with it any notion of blame : it simply denoted a person possessed of such political power as above mentioned, whether he used it well or ill. Many so-called tyrants were popular with the mass of the community, and were men of letters, and patrons of literature and art. They might appropriately be called kings or princes in the modern acceptation of those terms, except perhaps that the uncertainty of their tenure of power and the want of a recognised hereditary succession in the tyranny, or a regular mode of succeeding to it, would render the application of any modern name inappropriate.

In some passages in Herodotus (iii. 80, &c.; vi. 23, &c.; vii. 165) the words monarch and tyrant are used as synonymes to express an individual who possesses sovereign power; and in one instance at least (vi. 23, 24) he calls the same person king (*βασιλεύς*) and monarch (*μούναρχος*). Aristotle ('Polit.', iii. 7), after stating that a polity or government must either be in the hands of one or of a few, or of the many, adds that we are accustomed to call a monarchy which has regard to the interests of all members of the state a kingship (*βασιλεία*); and that a monarchy which has regard only to the interests of the monarch is a tyranny. In the case of Miltiades, who became tyrant of the Thracian Chersonesus, Nepos ('Miltiad.') remarks that "all persons are considered and called tyranni who enjoy lasting power in a state which has once been free." This definition seems to express pretty clearly the old Greek notion of a tyrant, but it leaves out of consideration the mode in which the power was acquired. Nepos remarks that Militiades was called "Tyrannus sed justus," "tyrant, but tyrant in constitutional form" (not *just*), for he had been elected by the people. Accordingly, he says in another place, he had the dignity or rank of king without the name. This is consistent with Herodotus (vi. 36), who says that the people made Miltiades tyrant (*τύραννον κατεστήσαντο*).

Among the Roman writers tyrannus is often used as simply equivalent to king, especially by the poets. Cicero couples dominus and tyrannus, thereby intending to use tyrannus in a bad sense, which was perhaps the more common acceptation of the word among the Romans in his time and subsequently. Seneca seems to refer to the original sense of tyrannus when he says, "A tyrant is to be distinguished from a king (rex) by his conduct, and not by the name : for Dionysius the elder (who was called a tyrant) was a better man than many kings; and Lucius Sulla may be appropriately called a tyrant, for he only ceased from slaughter when he had no more enemies to kill." (Facciol., 'Lex—Tyrannus.') According to this, a man might be called tyrant without being a cruel governor, for there were instances of persons so called who had used their power with moderation ; and yet a man who had not the title of tyrant might be called tyrant on account of his cruelty. It seems as if Seneca was trying to distinguish the popular use of tyrant in his time from its earlier historical signification. Tribellius Pollio has written the 'History of the Thirty Tyrants' who sprung up in the Roman empire in the time of Gallienus and Valerian. These so-called tyrants were not more tyrannical, in the modern sense of the term, than many Roman emperors.

The use of the modern words tyrant, tyranny, tyrannical, has been as vague as that of most other political terms. The term tyrant is properly limited to the government of one man who is sovereign, and the popular application of the term expresses disapprobation of his conduct. Aristotle's definition of tyranny would apply well enough to a modern tyrant : he is a sovereign who looks only to his own interest, or what he considers his own interest, and cares not what he does in order to accomplish his objects. But if he were a wise sovereign, and administered the state solely with a view to his real interest, that would be found in the main to coincide with the interest of the people, and he would not be called a tyrant, though perhaps he would come within Aristotle's definition. But Aristotle's language, though apparently precise, is not so, and he means by a tyrant administering the state for his own interest, that he also administers it to the detriment of the people. The word tyrannical is now often applied to acts of governments which are not monarchies ; but this is an improper use of the word. We may say that the laws enacted by the sovereign power in Great Britain are sometimes impolitic, unwise, or injurious to the state generally; they may also be sometimes called oppressive; but they cannot with propriety be called tyrannical, though such an expression may be and often is used in the vulgar sense of characterising a law which for some reason the person who uses the term does not like.

Confusion in the use of political terms, which is an index of confusion of thought, leads to absurdity in conduct. It is therefore a matter of some moment to clear up such confusion, which all people should try to do who presume to speak or write on matters political. A careful perusal of the following articles in this work, even if they should not be quite free from error, will put a man in the way of coming to right notions as to the meaning of ARISTOCRACY, CONSTITUTION, DEMOCRACY, KING, LAW, MONARCH, REPUBLIC, SOVEREIGNTY.

TYROSIN ($C_{18}H_{11}NO_6$). A colourless crystalline organic substance obtained along with LEUCIN, by the action of potash upon albumen, fibrin, casein, horn, hair, feathers, &c. It also exists ready formed in cochineal. It possesses neither acid nor alkaline properties.

U

U is at one extremity of the series of vowel sounds, lying next to the vowel *o*. In the Hebrew alphabet it does not appear, and was probably originally wanting in that of the Greek tongue. For the different forms of the letter see ALPHABET.

1. The close connection between this vowel and the vowel *o* might be inferred from their relative position in the vocal gamut, and has been already the subject of remark under the article O.

2. *ū* is interchangeable with the diphthongs *oe* or *oi* in Latin. Thus cūra, ūtor, ūnus, mūnio, mūrus, often appear in the older dialects of that language as coira or coera, oitor or oetor, oenus (observe the *w* sound at the beginning of the English word *one*), moinio or moenio, moerus. Hence the verb ūro is probably connected with oestrum, and also with aestus, aestas, as well as Vesta, Vesevus. In the same way foetus, foecundus, are formed from the old verb fuo, by the addition of the common suffixes *tus* and *cundus*, which are so often attached to verbs. Again the variation in the forms of Poeni and Punicus is an example of the same principle. It may be added, that all the words munus, munire, communis, immunis, munia, murus, are connected both in form and meaning with the Greek words, such as *μοιρα*, denoting *division*.

3. *u* with *au*, as in the Latin forms claudo and cludo, and the Latin mus compared with the German maus, a mouse.

4. A short *u* with *ă*. Thus those who represent the Arabic article in English characters are divided between al and ul.

5. A short *u* with *ĕ*. Thus the Greek tongue, or rather pen, prefers the syllable *el* where the Latin writes *ul*, particularly in the penult syllable: as Σικελος, Siculus: compare also the cry ελελελευ with the Latin ululare. The Germans again prefer *el*. Hence the Latin tabula, fabula, appear in German as tafel, fabel. The vowel *u* is also preferred by the Romans before *n*, if a *d* or *t* follow. Hence rediens has a genitive redeuntis, and faciundus is as common as faciendus.

6. A short *u* with *ĭ*. See I., s. 2.

7. For the interchange of *du* with *b* and *v*, see B, D.

8. For the interchange of *l* with *u*, see L.

9. *Ou* not unfrequently results from *on*, particularly in the Greek language, as *οδους* for *οδονς*; *τυπτουσι* for *τυπτοντι*; and the accusative plural of the second declension, *οικους*, is a corruption of *οικονς*, being formed from the singular *οικον* by the addition of the affix for plurality. Mr. Payne Knight appears to be wrong in inserting a digamma in this form.

10. For the loss of an initial *c* before *u*, see C. In confirmation of what is there stated, it may be observed that *uter* appears in an inscription which is determined by its contents to belong to the Augustan æra, in the form *cuter*, at least *neuter* is written *necuter*. The copyists, scandalised at such a form, altered it into *nec vero*, to the utter annihilation of the sense, until Marini again restored the true reading of the stone.

11. The insertion of a *y* sound before *u* is not limited to an initial *u*, as in union, university; but occurs in the middle of words. Thus, in Norfolk "true" is sometimes pronounced "tryoo." It is probably in this way that the English have adopted the orthography *ew* in so many words, as new, few.

12. For the intimate connection of *u* with V and W, see those letters.

UDAL TENURE. The Norwegian term "Udal," or "odel," appears to be the same as the German "adel," or "noble." Tenure is an improper name as applied to Udal land, for the land so called in Norway is not held by any tenure, but is free from all services. There is neither superior nor vassal, nor any of the consequences of such feudal relation as exists in many countries in Europe. (Laing's *Norway*.)

ULCER. [INFLAMMATION.]

ULEMA ('Ulemá), the collective name of the body of learned men in Turkey, is the plural of the Arabic "'Alim," "wise," and signifies originally "the wise men." The learned men in Turkey form a corporation which received its organisation from Mahmud-Pasha, grand-vizir of Mohammed II., the conqueror of Constantinople. In the larger meaning, the ulema consists of three classes, the mollahs mukreji, the mudaris, and the moultazims. From the first two classes are taken the interpreters of the laws, the principal mollahs, cadis, nazibs, muftis, and sheikhs; from the third, the lower cadis and khatibs. The imams and the inferior ministers of worship are not members of the ulema. The mufti, or Sheikh-ul-Islam, is the president of the ulema, and formerly had great political influence. No one can become a "muderri" (professor) or "kadi" (judge) except a member of the ulema, nor can any one be appointed chief judge or mufti without having previously occupied a subordinate place as judge or professor. An individual belonging to the ulema is called by the general name "mollah," or "a man of the law." In important cases, the mufti assembles the ulema, or as many of them as he judges convenient, and takes their opinion on the subject.

ULLAGE, a name given by gaugers to the part of a cask which is not filled with liquor: thus, if a cask, capable of holding 90 gallons, have only 80 gallons of spirits in it, there are 10 gallons of ullage.

ULMIC ACID. *Ulmin.* Some trees, and more especially the elm when it is old, secrete a liquid which dries as it exudes: the dry residue consists principally of mucilaginous matter, with some carbonate or acetate of potash, and eventually the mucilaginous matter undergoes a change, and, combining with the potash, forms a substance which was first examined by Vauquelin and Klaproth, and to which Dr. Thomson gave the name of *ulmin*. This name was changed by Berzelius to that of *geic* acid, because on treating soils with alkalies a considerable quantity of a similar compound is obtained.

Ulmin, or ulmic acid, may be artificially obtained, according to Braconnot, by the following process:—heat in a silver crucible equal weights of potash and sawdust, with a little water; the mixture is to be continually stirred: the mass softens and swells rapidly, and is then to be removed from the heat and stirred till cold: during the operation oxygen is absorbed from the air, owing to which the ulmic acid is formed. When cold, the product, which contains ulmate of potash, is dissolved in water, filtered, and treated with dilute sulphuric acid, which combines with the potash, and precipitates the ulmic acid from combination with it: the acid thus obtained is to be washed and dried. The properties of this ulmic acid are, that it is of a deep brown colour, very brittle, and breaks in angular fragments, and is almost insoluble in water. When precipitated from its solution in an alkali, it is in the state of hydrate, and it then dissolves in 1500 times its weight of boiling water, in 2500 times between 60° and 70° Fahr., and in 6000 times at 32°. The solution in cold water is brownish-yellow; that in hot is deep brown. *Moss water* owes its dark brown colour to the presence of ulmic acid.

It is insoluble in acidulated water or in saline solutions: sulphuric acid dissolves it without apparent alteration, and becomes blackish: water precipitates it from this solution. Ulmic acid reddens tincture of litmus. It is dissolved by alcohol, from which it separates in crystalline scales by spontaneous evaporation.

It has been already mentioned that ulmic acid may be obtained from soils: it may also be procured from rotten leaves, bog-earth, wood-soot, or turf, by digesting them in a weak solution of potash: by this a brown-coloured solution of ulmate of potash is formed, from which acids throw down ulmic acid.

According to Boullay, ulmin consists of—

Hydrogen	4·70
Carbon	57·64
Oxygen	37·66
	100·

Malaguti and Boullay, by treating sugar with dilute sulphuric acid, obtained two substances, which they supposed to be identical with ulmin and ulmic acid; but, according to Liebig, they are of a different nature, and he has given them the names of *sacchulmin* and *sacchulmic acid*.

ULMIN. [ULMIC ACID.]

ULMUS CAMPESTRIS, *Medical Properties of.* The bark of this species is officinal: it should be collected in spring from branches not too old: the outer bark is removed, and the interior, or *liber*, retained for use. When recent it is of a whitish-yellow colour, but when dried it is externally of a cinnamon hue, and curled up; the inner surface smooth; it is from a quarter to half a line in thickness, tough, fibrous, not easily powdered, devoid of smell, with a mucilaginous, bitterish, astringent taste.

The cold watery infusion becomes green on the addition of a solution of sesquichloride of iron, and a precipitate is thrown down by a solution of gelatine. It possesses demulcent, tonic, and astringent properties; and taken in full doses it accelerates the pulse, acting ultimately as a diaphoretic and diuretic. Though known from an early period as an astringent, it is little used at the present day, notwithstanding the testimony of Lettsom and others in favour of its utility in cutaneous diseases of a scaly kind. To do good it must be persevered in for many months, and the greater its action on the kidneys the greater the probability of ultimate benefit. Its agreeable taste reconciles many to the prolonged use of it, who would reject less pleasant medicines. It is one of the best substitutes for sarsaparilla. It is commonly administered in the form of decoction, but as the bark contains much starch, this is objectionable. An infusion made with cold water is far preferable. A pint or more of this is to be taken daily.

The *Ulmus fulva*, tawny-budded or slippery elm bark of America, is a very valuable demulcent, tonic, and astringent, and of great utility in the diarrhœas and dysenteries of the southern parts of the United

States. As an emollient this bark is of great service as an external application to wounds, bruises, chilblains, and cutaneous eruptions; for these it is generally made into a poultice. The bark of this tree is probably that which is termed *cortex unguentarius*, which is in high repute with the aborigines for the cure of wounds.

ULTRAMARINE. This beautiful blue pigment was originally made from the stone called *lapis lazuli;* and as the process was a tedious one, the price was enormously high. The lapis lazuli was analysed by Clement and Desormes; and their analysis led Guimet to the conception of producing artificial ultramarine. Other chemists, including Gmelin and Robiquet, devised other modes of attaining the same end; and now artificial ultramarine is a regular manufacture. The substance is made largely in Germany, but not much in England. One of the processes consists in taking equal parts of silica, sulphur, and carbonate of soda, grinding them up into a bluish-green mass, igniting them in the open air, and applying various finishing processes to the bluish powder which results. The artificial ultramarine thus produced is saleable at so low a price as 1*s.* 3*d.* per lb. It is very much cheaper than real ultramarine, and though inferior to that as a pigment, is more beautiful than smalt; hence it has come largely into use. The scientific journals have lately given a description of the ultramarine factory of Messrs. Zeltner and Heyne at Nürnberg, the chief makers of this pigment. The buildings are said to cover seven acres. The central building is a polygon of 24 sides; it has 12 compartments, 96 furnaces, 12 high chimneys, and 12 lines of tramways. The polygon is 136 feet in diameter. In various parts of the area are mills, steam-engines, washing apparatus, long ranges of drying rooms, and store rooms for 5000 or 6000 cwts. of artificial ultramarine. Two hundred persons are employed in this single manufacture. The best kinds of artificial ultramarine, used only by artists, pass through no less than eighty separate processes; but the commoner kinds, which are commercially more important, are coming largely into use in paper staining, sealing-wax making, calico printing, colour printing, and dyeing.

According to the experiments of Dr. Elsner, ultramarine must contain sulphuret of iron as well as sulphuret of sodium, and he has given the mean of several analyses of artificial ultramarine, of natural lapis lazuli, and of an artificial product by Varentrapp:—

	Lapis Lazuli.	Artificial, from Meissen.	Elsner.
Potash	..	1.75	..
Soda	9·09	21·47	40·
Alumina	31·67	23·30	29·5
Silica	45·50	45·00	40·0
Sulphur	0·95	1·68	4·0
Lime	3·52	0·02	..
Iron	0·86	1·06	1·0
Chlorine	0·42	..	..
Sulphuric acid	5·89	3·83	3·4
Water	0·12	..	..

UMBER. [Colouring Matters.]

UMBILICUS. This word has sometimes been applied to the focus of an ellipse; but in modern works, it stands for a point of a surface through which all its lines of curvature pass. At such a point the two principal curvatures are equal; but *point of spherical curvature is a better name.* ('Differential Calculus,' 'Library of Universal Knowledge,' p. 440.)

UMBRA. The Latin word has been used to signify the shadow of the earth or moon in an eclipse: the word *penumbra* is still retained [Eclipse] to signify that portion of the heavens which is partially shaded.

UMBRELLA, a shade carried over the head as a shelter from the rays of the sun, or from rain and snow. Although the name is applicable in either case, and perhaps most strictly in the former, the term *umbrella* is usually applied in this country only to such of these articles as are used as a protection against rain; while the name *parasol* is given to the light kind of umbrella carried by ladies as a defence from the heat of the sun. The French have a better distinction between the two kinds of umbrella; using the name *parasol* for those used to ward off the rays of the sun, and *parapluie* (from *pluie*, rain) for those used as a defence against inclement weather. Umbrellas were introduced into Europe, in comparatively recent times, from the East, where they have been used for shelter against the sun from time immemorial. Although pretty well known in London more than a century since, they did not come into general use for many years later. Jonas Hanway is said to have been one of the first men who commonly used an umbrella in England. At first they were kept in the halls of genteel houses, for holding over persons as they stepped to their carriages; and even long after they began to be used by pedestrians, they were considered signs of effeminacy if carried by males. Increased attention to comfort, and the reduced price of umbrellas, owing to improvement in their manufacture, have now rendered them almost as essential as articles of dress, even to the humblest classes.

The construction of common umbrellas, and the contrivances by which they are made to expand or collapse at pleasure, are too familiarly known to need description; and it is unnecessary to do more than mention some of the ingenious improvements which have been devised. In umbrellas of the ordinary construction the ends of the ribs are connected with the fixed ring upon the end of the stick, and the ends of the metallic rods called stretchers are attached to the sliding-tube, by rings of wire; so that the axes upon which they turn when the umbrella is opened and closed form arcs of a circle, instead of straight lines, by which excessive friction and destructive wear are occasioned. The outer ends of the stretchers, also, are connected with the ribs by means of axes or pins passed through the latter, by which they are so weakened that they frequently break. These defects are remedied in some modern umbrellas, by the adoption of ingenious though simple joints. Another new kind has a joint for connecting the stretchers with the ribs, allowing the framework to collapse into less space than usual, and preventing the fretting or wear of the cover at the ends of the stretchers. Very light and compact umbrellas are made with ribs of steel instead of whalebone or cane, which latter material, stained to resemble whalebone, is used in those of the commoner sort; and some of the best umbrellas and parasols are made with hollow or tubular metallic sticks, which combine lightness with strength.

In some of the umbrellas of recent invention, the ribs, sticks, strips and fillets are made of vulcanised india-rubber, a very tough yet elastic material. In Fox's patent umbrellas the ribs and stretchers are made of thin steel bent into the form of a hollow trough, by passing strips of metal between suitably shaped rollers, and annealing them frequently; the ribs and stretchers are thus made very strong although light, and their ends are properly shaped between steel dies. By Holland's patent, the ribs are made of elliptical hollow tubes. Mr. Pitton makes telescopic handles, and steel ribs with a folding hinge or joint. Many firms at Birmingham carry on the manufacture of umbrella furniture on a large scale, employing machines for every part of the work; even the little hinges which allow the handles of parasols to be folded are made to the extent of severals *tons* yearly.

UMBRIAN SCHOOL OF PAINTING. [Painting.]

UMPIRE. AWARD. The word umpire is sometimes used to denote the person who in the first instance decides a controversy; but in its legal sense it means a person named in the Submission, or under its authority, by the arbitrators [Arbitration] to decide the matters referred, which the arbitrators either cannot or will not decide.

The rules which govern an arbitrator regulate the conduct of the umpire also. If arbitrators agree upon certain matters referred to them, but are unable to agree upon others, the umpire may adopt and incorporate in his umpirage the former, and may himself decide upon the latter. If again arbitrators are unable to decide upon matters concerning which they have heard the evidence, they may report that evidence to the umpire, and his award thereon will be good, provided that before it was delivered neither party required of him to hear the evidence afresh.

UNCIA, the twelfth part of the As. The mathematicians of the 17th century frequently used this word to signify the numerical coefficient of an algebraical letter. Thus Halley ('Phil. Trans.,' No. 216) talks of "that admirable invention of Mr. Newton, whereby he determines the *Unciæ*, or numbers prefixed to the members composing powers," meaning to speak of what we should now call the numerical coefficients, which enter in any particular case of the binomial theorem.

UNDECAGON, a figure of eleven sides.

UNDETERMINED (Mathematics), not known, as distinguished from indeterminate, which cannot be known. Thus, "What numbers are those whose sum is 100?" is indeterminate: many numbers will satisfy the condition, but the problem contains no mode of distinguishing the answer which is wanted, nor of giving a preference to one answer over another. But an undetermined quantity may be determinate, or capable of being determined. There is, however, frequently a want of proper distinction in the use of these words. [Indeterminate.]

UNDULATORY THEORY OF LIGHT, a theory in which it is attempted to explain the phenomena of light by the supposed vibrations of an ethereal medium.

Descartes is considered as the first who entertained the opinion that vision might be so explained; but that philosopher only states that light may be a certain movement or action of the molecules of air and other pellucid substances. He supposes that the effects may be instantaneously transmitted to the eye; and he compares the apprehension of external objects by vision to that which a blind man obtains when, holding a staff at one of its extremities in the hand, the opposite extremity comes in contact with an obstacle. ('Dioptrices,' cap. 1.) Mallebranche appears to have conceived that there existed an analogy between the phenomena of sound and those of light; ascribing the former to vibratory movements of the particles of air, and the latter to the like movements of the particles of an ethereal medium between the luminous body and the eye. But Huygens ('Tractatus de Lumine') both advanced the undulatory hypothesis and explained by it the laws of reflection and refraction of light, not only for ordinary media, but also for Iceland spar, which possesses a powerful double refraction. Newton, however, adopted the corpuscular theory, having been influenced it would seem chiefly by the difficulty of accounting for the rectilinear propagation of a pencil of light, and the existence of shadows, on the undulatory hypothesis. The great reputation of

Newton, the simplicity with which the existence of rays fell in with the corpuscular compared with the undulatory theory, the want of sufficient familiarity with the conception of undulations, and the mathematical difficulties inherent in their investigation, conspired to retard the progress of the undulatory theory, and caused the corpuscular theory to be that chiefly in vogue up to the commencement of the present century. About that time the undulatory theory was revived by Dr. Young, who, guided by the analogy of sound, was led to the discovery of the important principle of interference [INTERFERENCE], and applied it successfully to the explanation of the colours of thin plates, and of the fringes seen in the middle of the shadow of a slender opaque body, which latter were proved to be *incontestably* due to interference, since they disappeared when the light which passed, or was about to pass by one side of the opaque body was intercepted by a screen, though the light which passed by the other side remained the same as before. The same principle, in the hands of Dr. Young, led to an explanation far more complete than any that had hitherto been given of various others of the curious phenomena of diffraction [DIFFRACTION OF LIGHT], and at his suggestion Dr. Wollaston undertook an experimental investigation of the laws of extraordinary refraction in Iceland spar, which ended in a complete verification of the construction which Huyghens had given under the guidance of the theory of undulations, a construction which was further verified by Malus in France, by observations made in a totally different manner.

Later still, Fresnel, in his celebrated memoir on diffraction, reduced the explanation of the phenomena of diffraction to two principles, Huyghens's principle, and the principle of interference, which are necessary consequences of the most fundamental assumptions of the undulatory theory, and proved by exact measures the accordance of theory and observation; and Fraunhofer, by observations on pure diffraction spectra, admitting of almost astronomical precision, verified the formulæ which result for that case from the principle of interference. Meanwhile a new and splendid class of phenomena, those relating to polarisation and the colours of crystalline plates, &c., engaged the attention of the most celebrated experimentalists; and though these for a time seemed difficult of explanation on any theory, they fell naturally into their places when the hypothesis of transverse vibrations [POLARISATION OF LIGHT], which occurred independently to Young and Fresnel, was introduced into the undulatory theory. Guided by this hypothesis, and by dynamical considerations, Fresnel constructed his celebrated theory of double refraction, which, without being, or professing to be, a perfectly rigorous mechanical theory, is one of the most wonderful scientific generalisations which the human mind has achieved; and while it explained the previously known laws of double refraction, and the polarisation of each of the refracted rays, corrected in some respects the laws previously assumed by experimentalists, and led to the discovery of new and unexpected phenomena. Thus while in the progress of optical science the corpuscular theory remained almost entirely barren of results, beyond the explanation of the laws of reflection and refraction and of the aberration of light, and even appeared to be contradicted by certain phenomena, the theory of undulations has continually been acquiring fresh strength, by bringing complicated phenomena into harmony with one another, and with the fundamental hypotheses of the theory. And within the last few years M. Foucault, by proving, *by direct experiment*, that light travels faster in air than in water, has given the *coup de grâce* to the corpuscular theory.

The fundamental assumptions of the undulatory theory are these: 1. That all space to the remotest visible star is filled with a rare and elastic medium, or *ether*, which also penetrates the substance of air, water, glass, and bodies in general. 2. That light consists in a succession of tremors or undulations propagated in this ether. 3. That self-luminous bodies, or rather their ultimate molecules, are in a state of vibratory agitation, which they are capable of communicating to the ether, in which they are propagated onwards by virtue of its elasticity, just as sonorous bodies are in a state of vibration, and communicate their vibrations to the surrounding air, by which they are propagated onwards in waves of sound. 4. That these ethereal vibrations are capable of affecting the nerves of the retina so as to produce the sensation of light, in a manner bearing a more or less close analogy to that in which the vibrations of the air affect the auditory nerves so as to produce the sensation of sound. 5. That, as in sound, *pitch* depends upon the frequency of the aërial vibrations, while for a note of given pitch *loudness* depends on the amplitude of the excursions to and fro of the particles of air, so in light *colour* depends on the frequency of the ethereal vibrations, while for light of a given kind *brightness* depends on the amplitude of the excursions of the particles of ether. 6. That the ethereal vibrations within refracting media are affected by the presence of the material particles in such a way as to be propagated with less velocity than in vacuo, whether it be from an increase of density of the ether, or a diminution of its elasticity, or from the ether having to thread its way among the material particles, or from some similar cause.

To a reader acquainted with the theory of sound the conception of an undulation is already familiar; but for the sake of others it may be well to use one or two illustrations. Conceive then a long rope to be stretched horizontally between a fixed support at one end, and the hand of a person holding it at the other. If the person now rapidly move his hand laterally and back again, the rope near the operator will be thrown into the form of a curve, and this curve will be seen to *travel* along the rope towards the fixed end. Yet it is evident that what so travels is not matter, but an affection of matter. The different portions of the rope merely move laterally to and fro: what progresses is a certain *state of things*, a state of displacement and motion which the different portions of the rope *assume in succession*. Again, if a stone be dropped into still water, a series of circular waves travel outwards from the point of disturbance, but the particles of water do not so progress, as may be seen by watching the motion of a floating cork, but merely move a little backwards and forwards, and up and down, oscillating about a mean position. Lastly, take the case of a gun fired in air. Here the air compressed by the explosion presses upon the quiescent air surrounding it, compressing it and at the same time moving it a little forwards; this shell of air acts in a similar manner upon the shell immediately outside it, and so on. Thus a wave of condensation (immediately followed, in point of fact, by a wave of rarefaction) is propagated outwards from the place of discharge, while the particles of air themselves merely move a little to and fro in the direction of propagation. In the first example undulations are propagated along a *line*, in the second along a *surface*, in the third *in space*, or in three dimensions; and in this respect the third example best illustrates the undulations which we contemplate in the theory of light.

In all cases of undulation we must carefully distinguish between the *velocity of propagation*, or the rate at which a certain *form* or *state of things* is propagated, and the *velocity of the particles* of the medium in which the undulations take place. The former depends only on the density and elasticity of the medium. Density we must conceive to be measured by the inertia of the portion of the medium contained in a given volume, and therefore we must attribute *inertia* to our supposed ether; but whether it possesses *weight*, whether it is subject to the influence of gravitation, is a question which we need not speculate about. By elasticity is merely meant the force whereby the medium tends to regain its primitive state, whether by resisting change of volume, as in the case of air, or change of figure, as in the case of india-rubber. We know that the velocity of propagation of sound in air is about 1100 feet per second, that of light in vacuo about 192,000 miles per second. The velocity of the particles may, however, be as small as we please; and in the theories of sound and light (with the exception, at least, of the explanation of certain phenomena relating to very violent sounds), it is sufficient to treat the motions of the particles as indefinitely small, so that we may apply the general dynamical principle of the superposition of small motions. In other words, if the medium (air or ether) would be disturbed in one way by one cause acting alone, and in another way by another, the actual disturbance at any point when the two causes act together will be got by compounding the disturbances (expressed by displacements or velocities, as the case may be) due to the two causes taken separately. The actual direction of motion of the particles of the medium may be left a perfectly open question so far as relates to the conception of an undulation and the explanation of phenomena thereby, and by the application of the principle of the co-existence of small motions. Thus, in the example of the rope, the motion is rectilinear, and perpendicular to the direction of propagation; and if the operator, instead of moving his hand backwards and forwards moved it round and round, the path of any particle would be a curve lying in a plane perpendicular to the direction of propagation. In the example of waves on water, each particle moves in a curve lying in a vertical plane passing through the direction of propagation; while in the third example the motion is simply to and fro in the direction of propagation.

A single pulsation of air is audible as a *noise*, though it does not convey the idea of pitch; but even in the most transitory light, such as that of the electric spark, the phenomena of dispersion and interference indicate that we have to deal with a succession of a great number of similar undulations. Returning, for simplicity of conception, to the illustration of the rope, let us therefore suppose that the operator moves his hand backwards and forwards in a regular periodic manner. The rope will be thrown into the form of a sinuous curve, which travels along it. The distance from any particle to the next before or behind which is in the same state of motion, is called the *length of a wave*. It is evident that a single wave-length comprises two bow-shaped portions of the curve, the displacements in which are on opposite sides of the mean position, and which may be distinguished as positive and negative; and also that any two points distant by half a wave's length are in exactly opposite states of displacement and motion, at least if we suppose the positive and negative portions of the curve exactly alike. If we reflect on the motion of any particular particle, we shall readily see that it goes through its changes once while the wave-form progresses by one wave's length. Hence, if v be the velocity of propagation, λ the length of a wave, and τ the periodic time of vibration of a single particle, we have the fundamental relation $\lambda = v\tau$, which applies to undulations in general, since what was said in the case of the rope holds good generally. In the case of light, the absence of prismatic colours when a star is displaced by aberration from its mean position, the absence of changes of colour when one of Jupiter's satellites enters or emerges from his shadow, and the existence of periodic stars, such as Algol, which rapidly change in brightness without changing in colour, indicate that the velocity of propagation of light in vacuo is the same for all colours. The phenomena of interference furnish us with means of measuring the length of a wave of light, which is found to vary from about 266 to 167 ten-millionths of an inch, in passing from the extreme red to the extreme violet. We infer, therefore, from the known velocity of propagation, that from about 458 to 727 millions of millions of vibrations must take place in one second.

The locus of the particles, which at a given instant are in the same state or *phase* of their motion, is called the *front of a wave.* When light diverges in the first instance in vacuum, or any singly refracting medium, from an element of a self-luminous body, the front of a wave is of course spherical, or, at a sufficient distance from the body, when we have to consider a small portion only of the front, sensibly plane, but after reflection or refraction it may be of any other form.

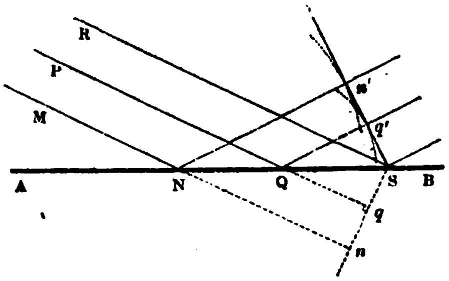
We now come to a principle of constant application in the theory of undulations, which is called Huygens's principle. It may be thus stated:—The front of a wave of light, either at a given instant, or as the parts of it arrive in succession at a given surface, may be divided into elements, of which each is conceived to be the centre of an elementary disturbance which spreads in all directions with the velocity appropriate to the medium in which it is propagated. The disturbance in front of the primary wave may be regarded as the aggregate of the elementary disturbances due to these secondary waves; and as these are insensible when taken separately, the aggregate disturbance will not be sensible except in the immediate neighbourhood of the envelope, or surface of ultimate intersection, of the secondary waves. If we confine our attention to a small portion of the primary wave, we shall have a corresponding small portion of the envelope, or general wave, in its advanced position, in the neighbourhood of which alone the disturbance due to the small element of the first wave is sensible. Hence the course of a *ray* from any point of the first wave is the line along which the point of ultimate intersection of the secondary waves which start from the neighbourhood of that point of the first wave is displaced. This is evidently the straight line joining the point last mentioned with the point of ultimate intersection at a given instant; or, again, the straight line joining the point in question of the first wave with the point in which the secondary wave thence diverging is touched by the general envelope.

The legitimacy of thus conceiving a wave to be broken up is a direct consequence of the general dynamical principle of the co-existence of small motions. The secondary waves will have an envelope behind as well as in front of the primary wave; yet we must not infer that the latter is propagated backwards as well as forwards. The explanation of the non-propagation in a backward direction, notwithstanding the legitimacy of thus supposing a wave broken up, belongs to the dynamical theory of diffraction, and is much too difficult a subject to be entered upon here. (See a paper in the 'Cambridge Philosophical Transactions,' vol. ix., p. 1.)

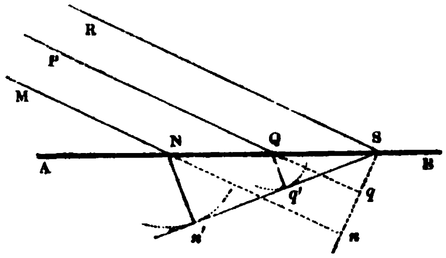
The complete explanation of the existence of rays requires this principle to be combined with the principle of interference, but for the present we shall confine ourselves to its application to the demonstration, according to the undulatory theory, of the laws of reflection and refraction. We may notice, however, in the mean time some features of the propagation of light in a uniform medium.

Conceive, then, a surface of any form to be at a given instant the front of a wave propagated in a uniform medium, and first suppose the velocity of propagation the same in all directions. If we conceive the wave broken up as above explained, the secondary waves, which will be all of the same magnitude, will by our supposition be spherical; and by very simple geometry we arrive at the following construction for determining the form of the wave in its onward course. At all points of the front of the wave at the time t draw normals, at the side towards which the wave is travelling, equal in length to $v\,t'$; the locus of the extremities of these normals will be the front of the wave at the time $t + t'$, and the normals themselves will be the courses of the rays. We learn also that it is not any arbitrarily chosen system of straight lines, the equations of which contain two arbitrary parameters, that can represent a possible system of rays; the lines must admit of being cut orthogonally by a system of surfaces. This geometrical property, so readily suggested by the theory of undulations, may of course be demonstrated as a consequence of the geometrical laws of reflection and refraction independently of any theory, the system being supposed to consist of rays which, having originally emanated from a point, have undergone any number of reflections and refractions. If the medium in which the wave is propagated be uniform, but differently constituted in different directions, as in the case of Iceland spar, for example, the velocity of propagation will vary with the direction, the secondary waves will no longer be spherical, and the course of a ray, while still rectilinear, will no longer be perpendicular to the front of the wave.

We come now to the explanation of ordinary reflection and refraction on the undulatory theory, according to the principles laid down by Huygens. We shall in the first instance, for the sake of simplicity, suppose the reflecting surface to be plane, and the incident waves to be plane likewise. Let the plane of the paper be the plane of incidence, and therefore perpendicular at the same time to the reflecting surface and to the planes of the waves. Let it cut the reflecting surface along A B; and let M N, P Q, R S, lying in the plane of the paper, be three normals to the incident waves, representing therefore the courses of incident rays. If there were no obstacle, the wave at one instant at N would, after the lapse of time required to describe the perpendicular distance of its plane from S, come into the position represented in section by S *q* *n*, perpendicular to R S, P Q *q*, and M N *n*. In order to examine the effect of the interruption, imagine each portion of the wave as it arrives at N S to become a centre of disturbance, from whence diverge hemispherical waves into the two media respectively, with the velocity appropriate to each. Consider for the present the first medium only. The times which have elapsed since the wave, now supposed to be at S, was at the points N, Q, - - -, are those required to describe N *n*, Q *q*, - - -, and therefore the radii N *n*′, Q *q*′, - - -, of the hemispherical waves which diverged from N, Q - - -, are equal to N *n*, Q *q* - - - - Through S draw a plane perpendicular to the plane of the paper, touching in *n*′ the hemisphere whose centre is at N. It is evident that the point *n*′ will lie in the plane of the paper, and that the plane S *n*′ will touch all the secondary waves, and therefore will be the front of the reflected wave. Moreover N *n*′, which is perpendicular to this plane, will represent the reflected ray corresponding to the incident ray of M N. Hence the reflected ray lies in the plane of incidence; and on account of the equality of the triangles S N *n*, S N *n*′, the angles S N *n*, S N *n*′, which are the complements of the angles of incidence and reflection, are equal, and therefore the angles of incidence and reflection are themselves equal.



Consider now the second medium. Everything will be the same as before, except that the radii N *n*′, Q *q*′, of the secondary waves diverging from N, Q, instead of being *equal*, will only be *proportional*, to N *n*, Q *q*, bearing to them the ratio of v' to v, where v' is the velocity of propagation in the second medium. The semicircles in which the hemispheres diverging from the various points of N S are cut by the plane of the paper will form a system of curves for which S is a centre of similitude; and it will be readily seen that if through S be drawn a plane perpendicular to the plane of the paper, and touching in *n*′ the hemisphere diverging from N, it will be the envelope of the secondary waves in the second medium, the point *n*′ will lie in the plane of the paper, and N *n*′ will be the course of the ray refracted at N, which will therefore lie in the plane of incidence. Also the angles N S *n*, N S *n*′, which are the complements of the angles S N *n*, S N *n*′, are equal to the angles of incidence and refraction respectively, and sine of incidence : sine of refraction :: N *n* ÷ N S : N *n*′ ÷ N S :: N *n* : N *n*′ :: $v : v'$, a ratio which is constant, that is, independent of the angle of incidence; which gives the law of refraction.



These laws may be easily extended to the general case in which the incident waves and the reflecting or refracting surface are of any form. For let P Q in either of the above figures represent a ray incident at Q, and therefore normal to the incident wave, and through Q imagine two tangent planes drawn, one to the incident wave, and the other to the reflecting or refracting surface. Confining our attention to the secondary waves which start in either medium from the immediate neighbourhood of the point Q, if we suppose them to start when a wave coinciding with the tangent plane to the wave, instead of the actual wave itself, arrives at the surface, and again, if we replace the actual surface by the tangent plane to it drawn through Q, we shall only commit an error on the position of the centre and magnitude of the radius of a secondary wave which is a small quantity of the second order, the distance of its centre from the point Q being deemed a small quantity of the first order. Hence the line of intersection of any two such secondary waves will only be rendered erroneous by a small quantity of the first order, which vanishes in the limit, and therefore the point of ultimate intersection of the secondary waves will not be affected. Hence the laws of reflection and refraction will remain the same as before, the normal to the surface at the point of incidence taking the place of the perpendicular to the plane.

This mode of conceiving of reflection and refraction shows at once that if the point of incidence be slightly varied, and a ray starting from a point in the incident, and reaching a point in the reflected or refracted ray, be supposed to follow the varied instead of the actual course, travelling in each medium with the velocity appropriate to it, the time of transit will be ultimately unchanged. This law may be readily extended to any number of reflections and refractions. In a great many cases the time of passage is less along the actual than along the varied course, in which case the proposition becomes equivalent to Fermat's law of swiftest propagation. The time may, however, be a maximum in place of a minimum, or neither a maximum nor a minimum. Thus, if a ray emanate from a point A, and after reflection at the point P reach the point B, the plane APB will be perpendicular to the tangent plane at P, to which AP, BP, will be equally inclined; and if A, B, be made the foci of a prolate spheroid of revolution, the magnitude of which is increased until it passes through the point P, it will there touch the reflecting surface. If now this surface touch the spheroid externally at the point P, the sum AP + PB will be a minimum when the point of incidence is slightly varied along the reflecting surface; but if it touch the spheroid internally, the sum will be a maximum; and if it both touch and cut the spheroid, so as to be external to it in some directions from P and internal in others, the sum will be neither a maximum nor a minimum.

When concentric waves fall on the surface of a concave mirror, the points on the latter which are successively reached by the waves become the centres of spherical reflected waves, the directions of whose motions tend towards the axis of the mirror; and the surfaces which touch all the secondary waves of like phase become those of as many general reflected waves of spherical or approximately spherical forms, having their convexities towards the mirror. These general waves go on contracting till they pass successively through some point in the axis, the form of the mirror being such as to permit the directions of the motions of the reflected waves to concur in a point; from this point, which is the focus of the mirror, they afterwards diverge as from a radiant point. It is easy to conceive that the general front of a wave formed by a surface which touches the secondary waves of like phase refracted in a transparent medium (at a convex surface, for example) may be spherical, and have its convexity towards the refracting surface. These waves will go on contracting, and pass successively through some point in the axis, provided the form of the surface of the medium be such as to permit the directions to concur in one point. This point is the focus, and from it, as from a radiant point, the concentric waves afterwards diverge.

In order that the relation between the sines of incidence and refraction may be conformable to the results of experiment, it is necessary to assume that the velocity of the waves is diminished when they enter a medium more dense than that in which they previously moved; and in this circumstance the undulatory theory is opposed to the theory of emission; for in the latter the velocity of light is supposed to be increased when it passes from any medium into one more dense. This led Arago to an apparently crucial experiment, to decide between the two theories. If a thin plate of mica be interposed in the path of one of two streams of light proceeding to interfere, the effect, according to the theory of emissions, will be to accelerate, according to that of undulations to retard, the stream passing through it. The direction in which the fringes are shifted, shows that the effect of the plate is the same as that of *increasing* the length of path of the stream passing through it, in accordance with the theory of undulations, and in direct contradiction, as it would appear, to the theory of emissions. However, as the decision is only arrived at by referring to another optical effect, depending for its explanation on the view we take of the nature of light, it is satisfactory to be able to refer to Foucault's celebrated experiment, mentioned at the commencement of this article, in which the same result is obtained by direct experiment. (See 'Annales de Chimie,' tom. 41, 1854, p. 129.)

From the demonstration of the law of refraction according to the undulatory theory, it follows that if μ be the refractive index of a substance, $v : v' :: \mu : 1$. Now, for a given substance μ depends upon the kind of light, increasing, though by no great fraction of the whole, in passing from the red to the violet. According to one of our fundamental suppositions, colour depends on the periodic time of the vibrations, and therefore we are obliged to suppose that one at least of the two velocities of propagation v, v', changes with the periodic time. This has to some appeared a formidable difficulty, inasmuch as theory and experiment combine in showing that musical notes of all degrees of pitch are propagated, in air with the same velocity, and calculation shows that this independence of velocity of propagation and periodic time must hold good in any homogeneous elastic medium in which undulations are propagated by virtue of the pressures or tensions called into play by the relative displacements within an indefinitely small element of the medium surrounding the point at which the pressure is estimated. To us the objection, even prior to the consideration of the mode in which the result may be accounted for, does not appear to be at all of this formidable character; for all the phenomena which bear on the subject conspire, as we have seen, to show that the velocity of propagation v in vacuo is the same for all colours, and therefore it is to a variation in v' that we are to look to account for the observed variation of μ. Now, according to our supposition, light is propagated within water, glass, &c., by the vibration of the ether within them. But the motion of one of two mutually interpenetrating media is so utterly different from anything we have to deal with in the theory of sound that we cannot reason from the one case to the other.

But further, a plausible mode of accounting for dispersion on the undulatory theory has been suggested, which not only removes the objection arising from the existence of a phenomenon which to some might appear inexplicable, but has led to the discovery of the approximate law of dispersion. Fresnel, in his memoir on double refraction, refers to a note, to appear at the end of the memoir, in which he explains dispersion by supposing that the forces by which the ethereal particles act on one another are sensible to a distance which is not infinitely small compared with the length of a wave. This appears to be by no means a violent supposition to make, when we consider the extreme smallness of λ. The note appears to have been lost, at least it does not accompany the memoir, but the subject was taken up by Cauchy, who has thus been led to express the square of the refractive index by a series according to inverse even powers of λ, the wave-length in vacuo. Restricting ourselves to the most important term, we thus get, by ordinary algebraic expansion, $\mu = A + B\lambda^{-2}$, A and B being constants depending on the nature of the medium, according to which expression $\Delta\mu$ ought to vary as $\Delta\lambda^{-2}$. And that this expression is no mere formula of interpolation, but contains a law of nature, any one may readily convince himself by taking Fraunhofer's indices for some kind of glass, and the wave-lengths of the fixed lines C, D, E, F, G, H, as determined by him by a diamond-ruled grating, and subtracting the logarithms of $\Delta\lambda^{-2}$ from those of $\Delta\mu$, Δ denoting the increments belonging to intervals such as C to D, D to E, C to E, &c., and then comparing the results with those obtained from a formula of interpolation taken at random, such as $\mu = A + B\lambda^{-1}$, or $\mu = A + B\lambda^{-3}$, similarly treated. The constancy of the differences of the logarithms in all the less refrangible part of the spectrum when the formula resulting from Cauchy's theory is used, cannot leave a moment's hesitation that the formula expresses a natural law. But if, accepting the formula as a true first approximation, we endeavour to ascend from it to the physical circumstances giving rise to it, we see that it merely indicates the existence, in the partial differential equation of motion, of a differential coefficient of the fourth order, without even completely specifying the variable or variables with respect to which the differentiation is taken. A result of such generality might well be obtained from a variety of physical hypotheses, so that we must not lay undue stress on the experimental verification of Cauchy's law in considering the evidence in favour of the physical theory from which he deduced it. Indeed, the fact, as it appears to be, of the absence of a chromatic variation of the velocity of propagation in vacuo, would seem to indicate that the molecules of ponderable matter play a very direct part in the phenomenon of dispersion.

Hitherto we have confined ourselves to the laws of reflection and refraction, which were in fact demonstrated by Huygens long before the principle of interference was known. Our subject naturally leads us, in the next place, to interference, to which a special article has already been devoted. [INTERFERENCE.] In that article the subject has been generally explained, and two fundamental experiments, due to Fresnel, have been mentioned, which show that interference is an essential property of light. We shall here, therefore, proceed to the formula which gives the intensity of the light resulting from the mixture of two interfering streams.

It will be necessary, in the first place, to express analytically the disturbance in a single stream of light. We shall suppose, for the sake of simplicity, that the waves are plane, and that the maximum accession of the particles of ether is the same at one point of space as another. This will be sufficient in any case, provided we confine our attention to a small portion only of the fronts of the waves, and to variations of distance in a direction perpendicular to the front, such that the change of intensity due to convergence or divergence need not be taken into account. Let the ether be referred to the rectangular axes of x, y, z, x being measured in the direction of propagation; let t be the time, and v the velocity of propagation. Since the waves are supposed plane, the disturbance will be independent of y and z, and therefore will depend only on x and t. Moreover, according to the fundamental notion of an undulation, whatever disturbance exists at the time t at the distance x from the origin will, after the lapse of the time δt, be found at a plane further in advance by δx, δn being connected with δt by the relation $\delta x = v\,\delta t$. Hence the disturbance remains the same, provided the difference between vt and x remains unchanged, and therefore for one value of $vt - x$ the disturbance will have one value, for another value another, and so on. In other words, the disturbance will be some function $\psi\,(vt - x)$ of $vt - x$, the direction of the motion of the particles being left a perfectly open question. The character of the undulations will depend on the form of the function ψ. Now we have seen reason to believe that in light we always have to deal with a succession of a great number of similar periodic disturbances, and, further, that the colour depends upon the periodic time. But in all optical phenomena the effects of lights of different colours are simply superposed, and therefore as regards the form of ψ we are justified in restricting ourselves to the consideration of a single regularly periodic function. Among such functions there is one which claims our special attention, namely, that which is expressed by a sine or cosine, or a mixture of the two, that is, $C \sin mw + C' \cos mw$, (w being written for $vt - x$), which again may be put under the form $a \sin (mw + \alpha)$. For in the first place, any dynamical system in a position of stable equilibrium, and therefore capable, on being disturbed, of performing small vibrations, has for its most general small motion a motion compounded of a finite or infinite number of motions, expressed, so far as the time is concerned, by a sine or cosine. If, therefore, we suppose the vibration of the molecules of the self-luminous body in the first instance to have been of this character, the same would have been impressed on the ether to which these vibrations were communicated. In the second place, by a known theorem any periodic function of w, going through its period when w is altered by $2\pi m^{-1}$, may be expressed by an infinite series of the form $A_0 + A_1 \cos mx + A_2 \cos 2mx + \cdots + B_1 \sin mx + B_2 \sin 2mx + \cdots$, where the first term vanishes if the mean value of the function be zero. By virtue of this theorem, and of the principle of the superposition of small motions, we should have a right to resolve the function ψ, supposing it merely to be periodic, into such a series of circular functions, and consider separately the disturbance due to each. Whether this be a *judicious* as well as a *legitimate* course to pursue, depends partly on whether any such resolution takes place *physically*, or whether, on the other hand, there are physical phenomena which we can refer to the *form* of the periodic function expressing the disturbance. In sound we have a sensible phenomenon, *quality*, which is referable to the form of the function expressing the disturbance, while vibrations of different periods are not, under ordinary circumstances, physically separated. But in light we have nothing answering to quality, and disturbances of different periods *are* physically separated, as in the phenomena of interference and diffraction as well as in dispersion. That disturbances expressed by a sine or cosine, rather than by some other periodic function, should be those which are propagated within a refracting medium with a unique velocity, and should not consequently be separated by prismatic refraction, follows from the general laws regulating the small motions of a system slightly disturbed from a position of stable equilibrium. We are led, therefore, by the phenomena with which we have to deal, to express the function ψ by means of a simple sine or cosine. If λ be the length of a wave, mx must change by 2π when x changes by λ, so that $m = 2\pi\lambda^{-1}$. Hence we may take as the standard expression for the disturbance—

$$a \sin \left\{ \frac{2\pi}{\lambda} (vt - x) + A \right\}$$

Suppose, now, that the ether at the same part of space is simultaneously agitated by a second series of undulations, which came originally from the same source. Suppose the directions of propagation to be so nearly the same that in considering, as above, a small portion only of the ether, we may treat them as the same, or the wave-fronts as parallel in the two series; and suppose the directions of vibration to be likewise the same in the two series, except as to a small angle depending upon and comparable with the small angle between the directions of propagation. Suppose, however, that the amplitude of excursion of the particles is different in the second series from what it is in the first, and further, that from having had to describe a longer or shorter path, or from any other cause, the undulations in the second series are ahead of or behind those in the first. Then we may represent the disturbance in the second series by

$$b \sin \left\{ \frac{2\pi}{\lambda} (vt - x) + B \right\}$$

And compounding the disturbances belonging to the two series, we shall have for the result

$$(a \cos A + b \cos B) \sin \frac{2\pi}{\lambda} (vt - x) + (a \sin A + b \sin B) \cos \frac{2\pi}{\lambda} (vt - x),$$

which may be transformed into

$$c \sin \left\{ \frac{2\pi}{\lambda} (vt - x) + C \right\}$$

c and C being given by the equations

$$(1.)\ c^2 = a^2 + b^2 + 2ab \cos (A - B)\ ; \quad (2.)\ \tan C = \frac{a \sin A + b \sin B}{a \cos A + b \cos B}.$$

We learn, therefore, that the resultant of the two series is an undulation of the same character as the component undulations, differing from them only in the magnitude of the coefficient of vibration, c, and in the state or *phase* of vibration at a given point of space and at a given instant, as determined by the value of C compared with those of A and B.

It is with c that we are chiefly concerned; the value of C does not enter into account unless when we have a third stream interfering with the two former. Now we see from the formula (1), that according to the value of $A - B$, c varies between two extreme limits, which are the sum and the difference of a and b. These are, the one greater, the other less, than the greater of the two a, b. Hence we see that two streams of light from the same source reinforce each other, or else give an effect less than that of the stronger stream alone, according to their difference of phase.

The question now arises, what precise function of the coefficient of vibration ought we to take as a measure of the intensity? Various considerations tend independently of each other to the same conclusion, —that we must take the *square* of the coefficient of vibration as a measure of the intensity. It will be sufficient here to mention one or two.

Suppose that we have two streams of light just as before, only that in this case they come from *independent* sources. The theoretical difference between the present case and the former consists in this, that in the former, whatever may affect the constant A equally affects B, and therefore leaves the difference $A - B$ unchanged; and whatever affects a affects b in the same proportion, which is not the case when the streams are independent. In the case of streams from the same source, we may, for example, suppose that the actual disturbance consists of a series of regular periodic disturbances followed by a distinct series, and that by another, and so on, there being a great number of such changes in one second. The mode of interference will not thus be affected. But in the case of independent streams, $A - B$, though constant, it may be, during a great number of successive undulations, will go through all sorts of values a great number of times in one second, and the mean value of the term $+2ab \cos. (A - B)$ in the expression for c^2 will be zero. If now we take the square of the coefficient of vibration for the measure of the intensity, we shall have for the intensity of the mixture of independent streams the mean value of $a^2 + b^2 + 2ab \cos (A - B)$, or $a^2 + b^2$; or the intensity will be the sum of the intensities of the separate streams, as it ought to be; whereas if we were to take some different function as a measure of the intensity that would not be the case. Again, all mathematical investigations relative to the propagation of small vibrations in a medium disturbed at one place show that at a great distance from the centre of disturbance the coefficient of vibration varies inversely as the distance. But experiment shows that the intensity of light varies inversely as the square of the distance, and we are thus led in a perfectly independent manner to the same conclusion.

If the interfering streams are of equal brightness, $b = a$, and the limits of the coefficient of vibration c of the resultant stream are o and $2a$, and those of the brightness o and $4a^2$, that is absolute darkness, and four times the brightness of either stream alone.

We shall apply these formulæ to express the intensity at any point of the field of view in the case of the mixture of two streams of light coming originally from a luminous point, and afterwards reflected from two slightly inclined mirrors. [INTERFERENCE.] Supposing, for simplicity, the light to be reflected in a plane perpendicular to the line of intersection of the planes of the mirrors, let a be the distance of the luminous point, and therefore that of either virtual image, from that line, b the distance from the same line to the focus of the lens with which the fringes are viewed, d the distance of the two images. Since the length of path of either stream is the same as if it had started from the virtual instead of the actual image, if we denote these images by I, I', and the point of the focal plane at which the brightness is sought by M, and if we take $c \sin \frac{2\pi}{\lambda} (vt - x)$ to denote the disturbance coming from I, that coming from I' must be denoted by $c \sin \frac{2\pi}{\lambda} \left\{ vt - x - (I'M - IM) \right\}$. Let O be the middle point of the line II'. It will be readily seen that the plane drawn through O and through the line of intersection of the planes of the mirrors will be perpendicular to II'. Let p, q be the co-ordinates of M, measured in the focal plane of the eye-lens, the first perpendicular, the second parallel, to the plane through O just mentioned, the origin being at the intersection of that plane with a plane through IOI' perpendicular to the mirrors. We shall suppose, in conformity with the experimental circumstances of the case, that d, p, q are small compared with a and b. Let $a' = \sqrt{(a^2 - \frac{1}{4} d^2)}$ be the distance of O from the intersection of the mirrors. Then $IM^2 = (a' + b)^2 + (p - \frac{1}{2}d)^2 + q^2$, $I'M^2 = (a' + b)^2 + (p + \frac{1}{2}d)^2 + q^2$, and $I'M - IM = (I'M^2 - IM^2) \div (I'M + IM) = 2pd \div (I'M + IM) = \frac{pd}{a' + b}$ nearly. We have therefore for the intensity (L) of the mixture—

$$L = 2c^2 + 2c^2 \cos \frac{2\pi pd}{\lambda(a' + b)} = 4c^2 \cos^2 \frac{\pi pd}{\lambda(a' + b)}.$$

Since L does not involve q, the illumination will be arranged in bars parallel to the axis of q, and it will be sufficient to discuss its variation along the axis of p. At a series of equidistant points, for which $p = o$ or a multiple of $\frac{\lambda(a' + b)}{d}$, L is a maximum, and equal to $4c^2$. At points midway between these, where therefore p is an odd multiple of half that quantity, L vanishes altogether. Hence we have a series of alternately bright and dark bars, extending on each side of the central plane, or that bisecting II' at right angles, which is in the middle of a bright bar. The scale of the system is found to depend upon the colour, decreasing from the red to the violet, from whence we infer that the wave length also decreases from the red to the violet. The obliteration of the bars at a moderate distance from the centre when white light is used has already been explained. [INTERFERENCE.]

From the expression for L we see that the mean illumination, or the value of $(p'+p'')^{-1}\int_{-p'}^{p''} \text{L}\,dp$ for a large value of $p'+p''$, is $2c^2$, which would be the uniform illumination, if the streams mixed without interfering. This is a particular example of a general principle from which inferences have already been drawn [ABSORPTION], that when two or more distinct streams of light interfere, no light is *destroyed* by interference, which merely causes a different distribution of the illumination.

If β be the breadth of a fringe, which may be measured by a micrometer, $\beta = \frac{\lambda(a'+b)}{d}$, whence $\lambda = \frac{\beta d}{a'+b}$. The distances a, b, to the former of which a' may be deemed equal, are not small, and can be measured without difficulty. The distance d was measured by Fresnel by placing a screen with a small round hole at a known distance from the mirrors, so that a slender beam of light from each of the images I, I′ passed through the hole, and measuring by a micrometer the distance between the centres of the beams at a known distance on the other side of the hole whence d is obtained from the measured distance by similar triangles. This is one method of measuring the length of a wave of light.

The excessive smallness of λ, indicated by this or any similar phenomenon of interference, leads to a complete explanation of one of the oldest difficulties belonging to the undulatory theory, the existence of rays and shadows. Conceive a broad beam of light to fall perpendicularly on a screen containing a moderately small aperture, and let us examine the disturbance produced at a point M, situated at a considerable distance on the other side of the screen. For greater simplicity we shall suppose the incident beam to come from a very distant point, so that the incident waves may be regarded as plane. By Huygens's principle each element of the front of a wave, as it arrives at the plane of the aperture, may be considered as the centre of an elementary disturbance which diverges into the space behind the screen, and in due time reaches M. But the disturbance at M will be by no means proportional to the size of the aperture, since the various secondary waves which at a given instant reach M, and which arise from incident waves which reach in succession the plane of the aperture, are in a condition to interfere. First, suppose M situated at some distance outside the geometrical projection of the aperture. Make M the centre of a number of spheres with radii increasing by $\frac{1}{2}\lambda$, and of which as many are drawn as cut the aperture. These spheres will cut the aperture into numerous narrow slips, of the form of portions of circular annuli, having for their common centre the projection N of the point M on the plane of the aperture. It will be readily seen that the aggregate effect of the secondary waves starting from the various elements of one slip will be as nearly as possible neutralised by that of the waves coming from the next slip. For the squares of the radii of the annuli increase in arithmetical progression, and therefore the areas of consecutive slips are equal, except as to the trifling difference due to the change in the angle subtended at N. Neglecting for the moment this small change, we readily see that to each element of the first slip corresponds an equal element of the second, at a distance from M different from that of the former element by $\frac{1}{2}\lambda$, and therefore the secondary waves belonging to these two elements will, as nearly as possible, neutralise each other's effect. Hence the joint effect of two consecutive slips as compared with that of either of them is a small quantity of the order λ, that is the ratio of λ to the other quantities involved, such as the difference of distance from M of opposite sides of the aperture. But as the number of slips is a large quantity of the order λ^{-1}, it might be supposed that the total effect was comparable with that of one slip. This however is not the case. For the effect of any slip taken along with half the effects of the two adjacent slips is a small quantity of the order λ^2, and the sum of all such, when we group the slips so as to take every alternate slip along with half the effect of its two neighbours, is only a small quantity of the order λ, unless it be in consequence of the want of compensation at the beginning and end of the series. But at the two ends, that is at the parts of the aperture nearest to and farthest from the point N, the length of the slips dwindles down to zero. The peculiar case in which a part of the boundary of the aperture is exactly circular, having its centre in N, which attaches itself to the theory of the bright point in the centre of the shadow of a circular disc, is supposed to be excluded from consideration. We infer therefore that the disturbance at a point M, situated as above described, is insensible.

Next suppose M to lie at some distance *inside* the geometrical projection of the boundary of the aperture. Imagine a series of spheres drawn as before around M, beginning with that which touches the plane of the aperture in the point N. The aperture will now be cut up as before, only that now for some distance round N the annuli will be complete, after which they will become incomplete, and will finally dwindle away to nothing. The neutralisation will in this case take place just as before, except as regards half the effect of the first annulus, or central circle of the system, and the disturbance will therefore be sensibly the same as if the screen were removed.

If the point M be situated near the geometrical projection of the boundary of the aperture, whether inside or outside, or if the aperture be so small that a few only of the spheres above mentioned cut it, the determination of the disturbance at M becomes a more difficult problem, and belongs to diffraction. The explanation of the existence of rays and shadows when the light is divergent, or the intercepting screen is not perpendicular to its course, is nearly the same as before.

We come now to the colours of thin plates, one of the first phenomena to the explanation of which the principle of interference was applied. As, however, the whole subject has been referred to the present article, we shall commence with a description of the phenomenon itself, and of its laws, as discovered by Newton. The colours of thin transparent lamina had previously been studied to a certain extent, by Boyle and by Hooke, and the latter of these philosophers produced the phenomena in the instructive form in which their laws have since been studied, namely, by placing two object-glasses in contact. It was in this form chiefly that they were studied by Newton, and from him the coloured rings formed by such glasses have been called Newton's rings.

In order to observe these rings conveniently, Newton placed two convex lenses of long foci (14 and 50 feet) in contact with each other at their vertices, keeping them together by means of three clamps at intervals on their circumferences, so that there was between them a very thin plate of air, concave on its upper and lower sides. On bringing the pair of lenses to an open window, and receiving the rays of light from the sky by reflection from them, there were observed, the plates being gently pressed together, seven series of coloured rings or bands about a black spot in the centre: beyond the seventh band the colours could scarcely be distinguished. The diameters of the bands being measured, where the colour in each was the brightest, Newton found that those diameters were proportional to the square roots of the series of odd numbers 1, 3, 5, 7, &c.; at the places where the colours were the least bright, the diameters were found to be proportional to the square roots of the series of even numbers 2, 4, 6, 8, &c. The radii of curvature of the lenses being known, Newton computed the thicknesses of the plate of air at the circumferences in which the colours of the bands had the greatest and least degrees of brightness; and he found ('Optices,' lib. ii.) that, at the most luminous part of the ring nearest to the centre, the thickness was equal to $\frac{1}{178000}$ inch; the thickness at the most obscure part of that ring was equal to $\frac{1}{178000}$ inch. Hence, from the law above mentioned, the thicknesses of the air at the most and least luminous parts of the succeeding rings may be obtained; those thicknesses being considered as proportional to the squares of the semidiameters of the rings.

If lenses whose surfaces have different curvatures are employed, it is always found that like tints are produced in the circumferences of circles at places where the intervals between the surfaces are equal, the eye being similarly situated, or a line supposed to be drawn to it from the centre making equal angles with a plane passing through all the rings; and this circumstance serves to show that the tints depend wholly on the distances between the lenses. If the angle made by the line drawn to the eye be diminished, the diameters of the rings will be increased, the tints remaining the same. Newton found that for moderate obliquities the same ring was formed where the distance between the lenses, or the thickness of the interposed plate of air, varied as the secant of the angle of incidence on the first surface of the lens, which in estimating this angle may be deemed a plate bounded by parallel surfaces. To include great obliquities he has given an empirical rule not sensibly differing from the simple rule of the secant except at great obliquities. It has since, however, been found by careful measures of the diameters of the rings at great obliquities, that the thickness where a given ring is formed is regulated by the simple law of the secant, and not by the more complicated formula given by Newton.

When the rings are formed by homogeneous light they are found to be more numerous than when the light is mixed, indeed they are almost countless when the homogeneity is sufficiently perfect; they are also of the same colour as the light, and are separated from one another by narrow spaces which are quite black. The diameters of the rings in the corresponding bands, at the places where the colours are the brightest, are different when the bands are formed by homogeneous lights of different colours, being least when the light is violet, and greatest when red; and Newton computed, from the measured diameters of the rings of different colours, the intervals between the lenses at the places where the brightest parts of the first rings from the centre are formed: these distances are found to be equal to $\frac{1}{78450}$ inch for extreme red rays, and $\frac{1}{112000}$ inch for extreme violet rays, which it may be observed are half the lengths of an undulation for those kinds of light.

The order and the dimensions of the coloured rings are the same, whether air occupy the space between the lenses or whether the latter be in the exhausted receiver of an air-pump: but when a transparent medium, as water, of greater refractive power than air, is interposed between them, the tints are fainter and the diameters of the rings are less; or smaller distances between the lenses are requisite in order to produce the same tints: it is ascertained that, with different media, these distances, in the case of a perpendicular incident ray, are inversely proportional to the refractive indices.

Corresponding rings of colour were observed by Newton in thin plates surrounded by media less dense than the plates: thus a bubble of soap-water exhibits, by the gradual subsidence of the fluid, rings of colour exactly conformable to those between glass lenses; and, before the bubble bursts, a dark spot about half an inch in diameter, is formed at its upper part. The like phenomena have been observed in thin plates of mica and in bubbles of glass blown so thin as to burst.

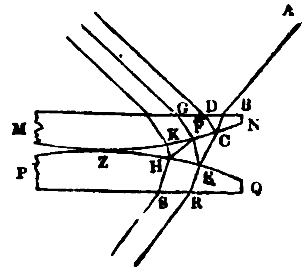
Newton also examined and described the phenomena of the coloured rings or bands between lenses when the light is transmitted through the latter. These rings are less bright than those which are formed by reflection; but when the obliquity of the transmitted rays to the plane of the rings is considerable they are sufficiently distinct: in the centre is a white spot, and the colours of all the rings are exactly complementary to those of the corresponding rings which are seen by the reflected rays. Newton's arrangement of the coloured tints in the first and second rings or bands, reckoning from the centre, is given in the following table, with the thicknesses of the plates of air, water, and glass, at the places where the tints are produced. The unit of measure is one millionth part of an inch.

Number of the Band.	Reflected Tints.	Transmitted Tints.	Air.	Water.	Glass.
I.	Very black	..	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{10}{31}$
	Black	White	1	$\frac{3}{4}$	$\frac{20}{31}$
	Nearly black	..	2	$1\frac{1}{2}$	$1\frac{2}{7}$
	Blue	Yellowish red	$2\frac{2}{5}$	$1\frac{4}{5}$	$1\frac{11}{20}$
	White	Black	$5\frac{1}{4}$	$3\frac{7}{8}$	$3\frac{2}{5}$
	Yellow	Violet	$7\frac{1}{9}$	$5\frac{1}{3}$	$4\frac{3}{5}$
	Orange	..	8	6	$5\frac{1}{6}$
	Red	Blue	9	$6\frac{3}{4}$	$5\frac{4}{5}$
II.	Violet	White	$11\frac{1}{6}$	$8\frac{3}{8}$	$7\frac{1}{5}$
	Indigo	..	$12\frac{5}{6}$	$9\frac{5}{8}$	$8\frac{2}{11}$
	Blue	Yellow	14	$10\frac{1}{2}$	9
	Green	Red	$15\frac{1}{8}$	$11\frac{1}{3}$	$9\frac{5}{7}$
	Yellow	Violet	$16\frac{2}{7}$	$12\frac{1}{5}$	$10\frac{2}{5}$
	Orange	..	$17\frac{2}{9}$	13	$11\frac{1}{9}$
	Bright red	Blue	$18\frac{1}{3}$	$13\frac{3}{4}$	$11\frac{5}{6}$
	Scarlet	..	$19\frac{2}{3}$	$14\frac{3}{4}$	$12\frac{2}{3}$

This table, extended so as to include the seventh band of reflected tints, constitutes that which is called Newton's Scale of Colours.

It was to explain the phenomena of these coloured rings that Newton proposed the hypothesis of 'Fits of easy Reflection and Transmission,' which in many respects explains the laws of the phenomenon. But besides giving no indication beforehand of what ought to be the variation of the diameter of a ring with the refractive index of the interposed medium, or with the obliquity of incidence, it tends to at least one result at variance with observation. According to the hypothesis of fits, the central black spot, as well as the dark parts of the rings seen with homogeneous light, ought to be of half the brightness of the brightest parts; according to the theory of undulations, they ought to be perfectly black. Observation shows, that at least the central spot (which is most easily observed, and does not require homogeneous light) is perfectly black.

A general explanation of the rings according to the principles of the undulatory theory may readily be given. Let M N P Q be two plates or spherical lenses, which we may suppose plano-convex (though all that is essential is, that the more curved of the adjacent surfaces should be convex), in contact with each other at Z; and let A B be the direction of a pencil, or of a wave of light incident upon the first or upper plate: this will be refracted in some direction as B C, and at the point C part of the pencil will emerge and fall on the other plate in some point E, where it will be partly transmitted through that plate in the direction E R, and partly reflected in the direction E F. Another part of the refracted pencil B C will be reflected at C in the direction C D, some of it emerging at D, and the rest being reflected back into the plate. The reflected pencil E F will also be, in part, transmitted through the upper plate in some direction as F G, and, in part, reflected in the direction F H: at the point H a portion will be transmitted in the direction H S, while another is reflected in the direction H K, and so on. The two principal reflected pencils are those of which the courses are A B C D and A B C E F G; and these being each once reflected will be of nearly equal intensity. The other pencils in the general reflected beam, having been reflected 3, 5, 7, &c. times, will be comparatively weak, except at very great incidences. The two principal transmitted pencils, A B C E R and A B C E F H S will be of very unequal intensity, the latter having been twice reflected, and the former not reflected at all. These will be accompanied by pencils reflected 4, 6, 8, &c. times, which will be comparatively insignificant.



Supposing, therefore, for the sake of simplicity, that the light is incident perpendicularly, restricting ourselves to the two most important pencils, and considering first the reflected light, we see that the light reflected from the under surface of the thin plate of air has had to travel a distance 2D in air more than the other stream, D being the distance between the lenses at the point under consideration, or the thickness of the plate of air. We might, therefore, perhaps, expect that the vibrations in the two streams would be in perfect accordance when D was equal to zero, or a multiple of $\frac{1}{2}\lambda$, and in opposition when D was an odd multiple of $\frac{1}{4}\lambda$. This would give correctly the law of the variation of the radii of the rings, since D varies as the square of the radius drawn from the point of contact of the lenses, with the single but important exception, that the places of the bright and dark rings are interchanged. But we must remark, that the two reflections take place under opposite circumstances, one at the surface of a rarer, the other at the surface of a denser medium. Various dynamical analogies, such as the reflection of sound from the end of a tube, according as it is closed or open, the reflection of sound at the common surface of two gases which are supposed not to mix, would make it more probable than the contrary supposition that in one of these two reflections there should be a change of sign, in the other not. A change of sign is equivalent to a change in the length of the path of one of the streams amounting to half an undulation. This change being admitted, theory assigns correctly the law of the variation of the radii of the bright and dark rings. And not only the *law of variation*, but the *absolute magnitude* of the rings may be assigned *à priori*, since the length of a wave of light is known by other observations; and the magnitude so assigned is in conformity with experiment. The explanation of the variation of the scale of the rings with the colour, and of the obliteration of the rings beyond the seventh or thereabouts by overlapping, when the incident light is white, is the same as in other cases of interference. Moreover, if a liquid such as water be interposed between the lenses in place of air, since light travels more slowly in water than in air, in the proportion of 1 to μ, the same kind of ring which with air is found at a spot where the distance between the lenses is D, is found with water where it is only $D\mu^{-1}$, which explains the law of variation of the radii of the rings with the refractive index of the interposed medium.

The explanation of the transmitted rings is perfectly similar, the chief differences being, first, that as the interfering streams have been refracted alike, and one of them in addition twice reflected, there is no change of sign, or the interference is determined simply by the difference of path, without the addition of the half undulation; and secondly, that the interfering streams are very unequal in intensity, and therefore with homogeneous light the minima are very far from being absolutely black. Thus when light is incident perpendicularly, whether externally or internally, at the common surface of crown glass and air, only about the $\frac{1}{25}$th part of the incident light is reflected, the remaining $\frac{24}{25}$ths being transmitted. Hence by two such reflections the intensity is reduced in the proportion of 625 to 1; and if we represent by unity the intensity of the light transmitted across the thin plate without reflection, the intensity of the twice reflected light must be represented by $\frac{1}{625}$. The question may naturally be asked, How can such feeble light by interfering with the former give rise to any sensible rings? The explanation of this paradox is derived from the consideration that in interference we must compound not *intensities* but *vibrations*, and thence deduce the intensity by taking the square of the coefficient of vibration. Thus, taking the above numbers as correct, we learn that the coefficient of vibration will be reduced by one reflection in the proportion of 5 to 1 only, and by two in the proportion of 25 to 1. Hence if we take the coefficient of vibration in the simply transmitted stream as unity, that in the twice reflected stream will be $\frac{1}{25}$, and therefore that in the resultant stream will vary between the limits $1 \pm \frac{1}{25}$, and the intensity will vary between the limits $(1 \pm \frac{1}{25})^2$, or $1 \pm \frac{2}{25}$, nearly; so that the difference between the limits is as much as $\frac{4}{25}$ths, or nearly $\frac{1}{6}$th of the mean intensity.

Next, suppose the light incident obliquely. If β be the angle of incidence on the first surface of the upper lens, or which is the same (the lens for this purpose being treated as a plate bounded by parallel surfaces), the angle of refraction into the thin plate of air, it may be shown, as in Airy's 'Tracts' ('Undulatory Theory,' art 64), or still more simply by referring everything to sections of the fronts of the waves by the plane of incidence instead of to rays, that the retardation due to the double transit across the plate is $2\,D \cos \beta$, in place of $2\,D$, as at a perpendicular incidence. This explains the law of the variation of the rings with the obliquity.

From the explanation hitherto given it might seem that in the case of the reflected rings the minima, though nearly, ought not to be perfectly black. For the stream reflected at the second surface of the thin plate has to undergo two more refractions than that reflected at the first surface, and at each refraction a small portion of the incident light would be lost to it by reflection. Fresnel first showed ('Annales de Chimie,' tom. 23, p. 129), by taking account of the infinite number of reflections, as Poisson had previously done in the case of a perpendicular incidence, that the minima in the reflected rings ought at any incidence to be perfectly black, and that, without assuming anything relative to the law of intensity in reflection beyond a law discovered experimentally by Arago, that at any obliquity light is reflected in the same proportion at the first and second surfaces of a transparent plate. For a very simple demonstration at the same time of Arago's law, and of the loss of a half undulation, on the assumption merely that the forces acting depend only on the positions of the particles, the reader is referred to a paper in the 'Cambridge and Dublin Mathematical Journal' (vol. iv. p. 1). A complete investigation of the intensities of the reflected and transmitted rings, in which account is taken of the infinite number of reflections, will be found in Airy's 'Tract,' arts. 64–67. The result is—

$$\text{For the reflected system} \quad \frac{4a^2e^2\sin^2\frac{\pi}{\lambda}\mathrm{v}}{(1-e^2)^2+4e^2\sin^2\frac{\pi}{\lambda}\mathrm{v}},$$

$$\text{For the transmitted system} \quad \frac{a^2(1-e^2)^2}{(1-e^2)^2+4e^2\sin^2\frac{\pi}{\lambda}\mathrm{v}},$$

where a denotes the coefficient of vibration for the incident light, v the retardation, $2\,\mathrm{D}\cos\beta$, and $1:e$ the ratio in which the coefficient of vibration is altered by one reflection. The sum of the two expressions is always equal to a^2, which shows that the reflected and refracted systems are complementary to each other, conformably to observation.

Sir Isaac Newton also discovered that when the sun's light is reflected into a darkened room, and allowed to fall on a screen with a moderately small hole, and the beam so passing is received perpendicularly on a concave mirror, made of glass quicksilvered at the back, which is placed at such a distance from the screen that the hole coincides with the centre of curvature of its surfaces, so that the regularly reflected light goes back through the same small hole by which it entered, a system of coloured rings is seen depicted on the screen, on the face towards the mirror, surrounding the hole. The order of colours, and the law of the diameters of the rings, agree with the transmitted system of the rings formed between two object-glasses. A metallic speculum exhibits no such rings. If the amalgam be removed from a mirror of quicksilvered glass, the rings are seen as before, but much fainter. With different mirrors the diameter of a given ring varies directly as the radius of curvature of the surfaces, and inversely as the square root of the thickness of the glass.

Although Newton expressly refers to the defect of polish of the first surface in relation to these rings, he does not seem to have purposely tarnished his mirrors. In repeating Newton's experiments, the Duke de Chaulnes observed that the brilliancy of the rings was very greatly increased by tarnishing the surface, for which milk much diluted with water is very convenient. It is advantageous to form a diverging beam by transmitting a beam of sunlight through a pretty large lens, at the focus of which is to be placed the small hole of the screen. In this way of operating the experiment is one of remarkable beauty. On slightly inclining the mirror, the phenomenon changes in a very remarkable way, a set of coloured rings continually opening out from a point midway between the luminous point, or image of the sun in the focus of the lens, and its image formed by regular reflection. The experiment may be varied in a very beautiful way by dispensing with screen and sunlight, and simply placing a small taper-flame in front of the tarnished mirror, in such a position as to coincide with its inverted image. On viewing the coincident flame and image, they are seen surrounded by a splendid series of coloured rings, which appear to have a determinate position in the air like an actual object.

These phenomena are known as the *colours of thick* plates. They have been shown to arise from the interference of two streams of light, whereof one is scattered on entering the glass, and then regularly reflected at the back and refracted out; and the other enters the glass by regular refraction, and after regular reflection at the back is scattered in emerging. At a point coinciding with the luminous point and its image, the two scattered streams follow the course of the regular light, and therefore their difference of path is nothing, and the difference of path of the two scattered streams, which reach a point at no great distance from the former, will accordingly be sufficiently small to allow the streams to manifest the ordinary phenomena of interference. The theory of the rings for the most important case, that in which the luminous point is in the centre of curvature of the mirror, is given in Sir John Herschel's 'Treatise on Light,' arts. 679, &c.

Dr. Whewell and M. Quetelet observed a system of coloured bands, which are seen when the flame of a candle held near the eye is viewed by reflection in a common looking-glass, several feet off, with a tarnished surface. To see them distinctly, the image of the flame must be seen distinctly, so that an eye-glass must be used if required. They change with every change of position of the candle or of the eye, and with both eyes a double system is seen, one with each eye. Their explanation depends on the same principles as that of the rings formed by concave mirrors of quicksilvered glass, and the theory of both kinds will be found treated with great detail in a paper published in the 'Cambridge Philosophical Transactions,' vol. ix., part 2, p. 147.

The subject of diffraction has been already briefly considered in a special article. [DIFFRACTION OF LIGHT.] The full comparison of theory and experiment with reference to this curious and interesting class of phenomena, requires far too much mathematical calculation to be here introduced, and reference must be made to Airy's Tract on the Undulatory Theory, or other works in which the question is treated. Suffice it to remark, that the undulatory theory has led to a most complete explanation of the phenomena, qualitatively and quantitatively, in their minutest details.

There is one phenomenon, the astronomical phenomenon of aberration, the explanation of which on the corpuscular theory is so simple as to attract little notice, but which presents a serious difficulty on the theory of undulations. To account for it, it has been supposed by Dr. Young and others, that the earth in its motion round the sun passes through the ether without disturbing it, allowing it to pass between its own particles like the wind through a grove of trees. Startling as this hypothesis is, we ought not to reject it on the strength merely of previous notions respecting such a mysteriously subtle medium as the luminiferous ether, if we were fairly led to it. But we are not obliged to have recourse to it, for the phenomenon admits of explanation by attributing to the ether a motion, due to bodies passing through it, which is of a kind with which we have a great deal to do in hydrodynamics. (See 'Philosophical Magazine,' vol. xxvii. (1845), p. 9, and several subsequent articles.)

In the explanation of the phenomena which we have hitherto considered, nothing depends upon the direction of vibration of the particles of ether which transmit the waves, but the phenomena of polarisation lead us to suppose that the vibrations are transverse to the direction of propagation. [POLARISATION OF LIGHT.] This supposition being admitted, the curious and complicated phenomena of the interference of polarised light are explained with beautiful simplicity. We have in this article to consider how far the same hypothesis of transverse vibrations helps us towards an explanation of double refraction.

We shall commence by briefly adverting to the facts of double refraction, and to its laws so far as they were ascertained before Fresnel's researches on the subject. It was in Iceland spar that the phenomenon was first discovered, and this crystal, from the great power of its double refraction was well suited for a study of the subject, especially at a time when the instrumental means of examination were far inferior to what we at present possess. Of the two rays into which Iceland spar divides in general a single ray incident upon it, the more refracted was found to obey the ordinary law of refraction, but the less refracted was found to obey a more complicated law, not even lying in the plane of incidence, except in particular cases. On measuring the refractive index of the spar with respect to the latter or extraordinary ray by methods applicable to ordinary media, different values were obtained, varying from a maximum equal to the refractive index for the ordinary ray, and obtained when the course of the ray within the crystal was parallel to the axis, to a minimum, which was obtained in any direction perpendicular to the axis, around which everything relating to the optical properties was symmetrical. Since there are here two rays, we must, if we adopt the undulatory theory at all, assume that a disturbance excited at any point of the crystal would give rise not to one wave, but to two waves, diverging from that point, or what comes to the same, to a wave represented by a surface of two sheets. As the more refracted ray in Iceland spar obeys the ordinary law of refraction, the inner sheet of this surface must be supposed to be a sphere. The facts which have been mentioned respecting the refraction of the extraordinary ray, show that the outer sheet must be a surface of revolution around the axis of the crystal, along which it touches the inner sheet, and must be most protuberant at the equator. Apparently as being next in simplicity to a sphere, Huygens assumed this surface or sheet to be an oblate spheroid of revolution, and found the calculations thence resulting as to the course of the extraordinary ray confirmed by the result of his experiments.

The demonstration of the laws of reflection and refraction in the case of ordinary media, require but a slight modification to adapt them to the case of a crystal for which we are supposed to know the form of the wave surface. In fact, if we suppose, for simplicity, the incident waves and the surface of the crystal to be both plane, we have only to replace the hemispheres within the media by the corresponding wave surfaces, which will form a system of similar and similarly situated curved surfaces with two plane envelopes, one for each sheet. Hence results the following construction. Draw a line perpendicular to the incident waves in air, and therefore representing the course of an incident ray. With the point of incidence for centre, describe a sphere representing the velocity of propagation in air, and likewise within the refracting medium draw the wave surface on a corresponding scale, so that its radius in any direction represents the velocity of a ray propagated in that direction. Produce the incident ray to meet the sphere within the refracting medium which is a continuation of the hemisphere described in air, and at the point of meeting draw a tangent plane to the sphere, or, in other words, a plane perpendicular to the ray. Through the line of intersection of this tangent plane with the plane of the surface, draw tangent planes to the two sheets respectively of the wave surface, and join the point of incidence with the points of contact. The two tangent planes will give the directions of the fronts of the two refracted waves, while the two joining-lines will give in direction the courses, and in magnitude the velocities, of propagation, of the two refracted rays; and if from the point of incidence we let fall perpendiculars on the two tangent planes, they will represent in magnitude and direction the velocities of propagation of the refracted waves, estimated in directions perpendicular to their planes. If the incident waves and the surface of the medium be curved, the same construction will hold good on substituting tangent planes for these curved surfaces, just as in the case of ordinary media, but the front of either refracted wave will of course no longer be plane but curved. A construction based on the same principles gives the courses of internally reflected rays; and it may be remarked that a single incident ray in general gives rise to two internally reflected rays.

The accuracy of Huygens's construction, as has been already observed, was confirmed by the observations of Wollaston and Malus, and it was for some time supposed that other doubly refracting crystals resembled Iceland spar, except as to the energy of their double refraction. But Biot discovered that in quartz and several other doubly refracting crystals it is the *less* refracted instead of the *more* refracted of the two rays which obeys the ordinary law of refraction, so that in the application of Huygens's construction the oblate must be replaced by a prolate spheroid. This difference does not entail any difference in the state of polarisation: it is still the ordinary ray that is polarised in a principal plane. Crystals in which, as in Iceland spar, the ordinary ray is the more refracted, have been called negative, and those of the other class positive; terms derived from certain views relating to the corpuscular theory.

If a plate of Iceland spar cut in a direction perpendicular to the axis be interposed between the polariser and the analyser of a polarising apparatus, a most splendid series of coloured rings make their appearance. If the analyser had been turned till the field was dark, the rings are seen to be interrupted by a black cross, the arms of which are parallel and perpendicular to the plane of primitive polarisation, and the order of the tints, beginning from the centre, agrees with that of the reflected system of Newton's rings. If the analyser be turned through 90°, the black cross is replaced by a white one in the same position, and the tints now agree with the transmitted system of Newton's rings, but are much more vivid. In intermediate positions of the analyser, the rings are less vivid, and are interrupted by a double cross containing white light of mean intensity, or, in other words, by eight radii, of which every alternate pair are at right angles. The arms of the crosses are parallel and perpendicular to the planes of polarisation of the polariser and the analyser. Similar rings are seen in the case of other doubly refracting crystals of the class now known as uniaxal; but sometimes, in consequence of a great chromatic variation in the doubly refracting power of the crystal, the succession of tints deviates materially from that of Newton's rings.

In quartz, the phenomena manifested by polarised light passing nearly along the axis appeared peculiar, resembling a combination of those belonging to an ordinary uniaxal crystal with those belonging to syrup of sugar; but the same have recently been discovered in some other uniaxal crystals.

In investigating the colours exhibited by crystalline plates, Sir David Brewster was led to the discovery that in many—in fact, in the greater number—of crystals, there exist not *one*, but *two*, directions about which coloured rings are seen in polarised light. Such crystals are called *biaxal*, and the two directions in question are called the *optic axes*. Sometimes, as in sulphate of lime, sugar, &c., the optic axes are widely separated; and in this case, if a crystal cut perpendicularly to either axis be introduced into the previously dark field of a polarising apparatus, a series of nearly circular coloured rings is seen interrupted by *a single* dark brush, in place of the pair of brushes forming a cross which are seen in uniaxal crystals. If the crystal be turned round an axis coinciding with the optic axis, the black brush turns round in a contrary direction at an equal rate relatively to space, or a double rate relatively to the crystal, whereas in a uniaxal crystal similarly treated the black cross remains stationary. The rings are ordinarily nearly equidistant, whereas in a uniaxal crystal they obey the law of increase of Newton's rings, the squares of their radii increasing in arithmetical progression. In other crystals, like nitre, the optic axes are near each other, and may be seen together, especially if the plate be cut in a direction perpendicular to their middle line. In this case, on introducing the crystal into the dark field a set of coloured curves are seen resembling lemniscates, having the optic axes for poles; and each optic axis is traversed by a dark hyperbolic brush; and at certain azimuths of the crystal, 90° apart, the two brushes unite and form a cross, one arm of which passes through the optic axes.

Sir David Brewster also discovered the relation between the optical characters of crystals and their crystallographic forms. It was found that the system of rectangular axes formed by lines bisecting the acute and obtuse angle between the optic axes, and a line perpendicular to their plane, were intimately connected with the crystalline form, so that whenever there existed a plane of crystalline symmetry, two of these axes lay in it. It is found that crystals of the cubic system are singly refracting, those of the rhombohedral and pyramidal systems uniaxal, and those of the prismatic, oblique, and anorthic systems biaxal. No account is here taken of properties like those of syrup of sugar, nor of what Biot has termed lamellar polarisation.

The explanation of these beautiful coloured rings and curves follows at once from combining the observed laws of double refraction, including therein the polarisation of the refracted rays, with the laws of the interference of polarised light. The latter, as we have seen, admit of a perfectly simple explanation on the hypothesis of transverse vibrations; it remains to be seen what account that hypothesis can give of the former.

For some time after the discovery of biaxal crystals, it was supposed that one of the refracted rays followed the law of ordinary refraction, while the other followed some unknown law more complicated than the Huygenian. It was theory which first pointed out to Fresnel, that neither ray followed the ordinary law, an anticipation which he found to be confirmed by experiment.

Our limits would not permit us to enter into the theory of double refraction as given by Fresnel; we shall content ourselves with a brief notice of the principles of the investigation, and a statement of the results to which it conducted him.

In any theory of double refraction, there are two kinds of laws which have to be accounted for; those which regulate the velocity of propagation, and those which regulate the state of polarisation. For the two are evidently so bound up together, that any true theory ought to explain both at the same time.

With regard to the former, if we only knew the form of the wave-surface, all the rest would follow from Huygens's construction. To determine, however, the propagation of a disturbance spreading out on all sides, is a problem presenting many difficulties, some of which may be evaded by the following consideration. Imagine an infinite number of plane waves, the effect of which, severally, is infinitely small, to pass initially through the point from which the disturbance is supposed to emanate. These will serve to represent initially the disturbance in the neighbourhood of that point, and their effect will elsewhere be insensible. As the time progresses, they will travel along with the velocities belonging to plane waves in their respective directions, and their effect will be insensible except along the surface of their ultimate intersections, which, therefore, will be the wave-surface required. Hence, everything is reduced to the determination of the mode of propagation of a plane wave in an arbitrary direction.

This problem Fresnel endeavoured to solve by regarding the ether within a crystal as made up of distinct particles acting on one another with forces which are functions of the distances, and considering in the first instance the motion of a single particle supposed to be alone disturbed. The result is, however, meant to be applied to a whole plane of particles constituting a wave, and this application is kept in view throughout the investigation. The force of restitution called into play by the displacement is accordingly resolved in a direction parallel and perpendicular to the front of the wave, and it is assumed that the latter component produces no effect, because although a single particle would be as free to move in that as in any other direction if impelled, a plane of particles could not so move without compression, whereas vibrations which are strictly transversal take place without compression, to which Fresnel supposes the ether would oppose an immense resistance. Accordingly account is taken only of that component of the force of restitution which lies in the plane of the wave, and which therefore the particle, considered as one of a plane of particles, would be free to obey. It is shown that for either of two rectangular displacements parallel to the front of the wave, the component of the force of restitution which is parallel to the front is also in the direction of displacement, but for a given displacement the force of restitution is different in these two directions. If now the initial displacement be parallel to the front of the wave, but otherwise arbitrary, and if it be resolved in these two directions, the components will be propagated independently of each other, but with different velocities. This accounts both for the double velocity of propagation and for the polarisation, in rectangular planes, of the disturbance propagated with the two velocities respectively.

These results were mainly deduced from a consideration of the force of restitution called into play by an *absolute* displacement, whereas it belongs to the fundamental conception of the mechanism of an undulation that it is propagated by forces called into play by *relative* displacements. This difficulty by no means escaped Fresnel, who endeavoured to show, by probable reasoning, that the general results would still be the same.

The actual results which follow from Fresnel's theory may be enunciated in the following laws:—

(1.) In every crystal there exists a system of three rectangular axes (axes of elasticity), with respect to which the optical phenomena are symmetrical. (2.) Let a, b, c, be three parameters belonging to these axes respectively, and representing certain velocities of propagation; construct the ellipsoid $a^2x^2+b^2y^2+c^2z^2=1$, and cut it by a diametral plane parallel to the front of a wave, the reciprocals of the semi-axes of the elliptic section will represent the two normal velocities of the waves which can travel independently in the given direction, and planes perpendicular to the wave front and to the respective semi-axes will be the corresponding planes of polarisation.

These laws are of a nature to admit of comparison with experiment, either directly or by the consequences which mathematically flow from them. The direction of vibration in polarised light is not itself cognisable by the senses. In the theory from which Fresnel deduced the above laws, it is supposed that the direction of vibration is *perpendicular* to the plane of polarisation.

The deduction of the form of the wave-surface becomes now a mere geometrical problem of envelopes. Fresnel did not succeed in solving the problem directly on account of the difficulty of the elimination, but he gave a very elegant construction by points of a surface which he afterwards proved to be the wave-surface required, by showing that it satisfied the requisite condition as to tangent planes, and he thus obtained its equation. The construction is as follows. Construct the ellipsoid $a^{-2}x^2+b^{-2}y^2+c^{-2}z^2=1$, cut it by a diametral plane, and from the centre perpendicular to this plane draw lines equal respectively to the semi-axes of the elliptic section: the locus of their extremities will be the wave-surface. In the 'Cambridge Philosophical Transactions,' vol. vi., p. 85, Mr. A. Smith has very simply obtained the equation of the surface, regarded as an envelope, by direct elimination. The equation is—

$$\frac{a^2x^2}{r^2-a^2}+\frac{b^2y^2}{r^2-b^2}+\frac{c^2z^2}{r^2-c^2}=0,$$

where $r^2=x^2+y^2+z^2$. It is readily seen that when two of the parameters, a, b, c, become equal, the wave-surface of Fresnel becomes the sphere and spheroid of Huygens. For an admirable dynamical investigation of the problem of double refraction, the reader is referred to a paper by Green, in the 7th vol. of the 'Cambridge Philosophical Transactions.'

The length to which this article has already run, compels us to omit the subjects of conical refraction, the application of the undulatory theory to the determination of the intensities of reflected and refracted polarised light, and of the change of phase which accompanies total internal reflection, the properties of metals in relation to the reflection of light, the optical properties of syrup of sugar and other active liquids, and those of transparent uncrystallised media subject to the action of a powerful magnet. For these, reference must be made either to the original memoirs of those who have investigated these subjects, or to some of the extensive treatises which have been written on the undulatory theory.

UNGUENTS, or ointments, are unctuous substances, for external application, and intended to answer a variety of purposes, according to their composition. They are variously designated according to their nature and consistence. At one stage of surgery they were of a very complicated kind, as may still be seen in the so-called balsams (artificial) of the continental pharmacopœias; but the progress of modern science leading to greater simplicity, their numbers are much reduced, and their ingredients fewer. If they are composed chiefly of wax, without resin, and of oil, with or without other more active materials, and have a consistence nearly as great as that of plasters, they are termed *cerates;* when fats or resin are used, so that the consistence is scarcely greater than that of butter, they are termed *ointments;* if distilled fragrant waters or essential oils are used, they are termed *pomatums*, or *pomades;* and occasionally, if the appearance correspond, some are termed *butters*, or *pastes*, such as *almond paste*, which, being bland and emollient, must be carefully distinguished from some other compounds also called butters [BUTTERS, in Pharmacy], which are acrid and corrosive, such as butter of antimony, or violent poisons, such as butter of arsenic. Most ointments are formed by melting together the ingredients, and in doing this the heat should never exceed that of the boiling-point of water. To ensure uniformity and smoothness, the ingredients should be carefully stirred while on the fire, and strained through a cloth while yet in the liquid state; if essential oils are used, these must be added afterwards. Some are made by merely triturating the materials together, as in the case of mercurial ointment. No great quantity of any ointment should be prepared at one time, as they are apt to undergo changes, sometimes very detrimental, either by the ingredients acting on each other, or by absorbing oxygen from the air. Many should be prepared only when wanted, such as the ointment of the nitrate of silver.

The chief use of ointments is either by their emollient qualities to soften tense or hardened parts, or to sheath excoriated parts from acrid secretions or the irritation of the air. Applied to ulcers, they may, according to their nature, besides excluding the air, promote the healing, if judiciously used, or hinder it if improperly used. For chapped hands or rough skins, one of the mildest and safest applications is almond-paste.

UNGULA. The hoof of a horse looks like the part of a cone which is separated from the part containing the vertex by an oblique plane. Hence such a solid is called an ungula, and rules for the determination of its content are given in books of mensuration.

UNIAXAL CRYSTALS. [OPTIC AXIS.]

UNICORN. "Concerning the Unicorn, different opinions prevail among authors," says the author of 'Thaumatographia Naturalis' (1633), and he adds that some doubt, others deny, and a third class affirm its existence.

Ctesias, the author probably whom Aristotle followed, describes the Wild Asses of India (ὄνοι ἄγριοι) as equal to the horse in size, and even larger, with white bodies, red heads, bluish eyes, and a horn on the forehead a cubit in length. For the space of two palms from the forehead this horn is entirely white, the middle part is black, and the extremity is red and pointed. Drinking-vessels are made of it, and those who use them are subject neither to convulsions, epilepsy, nor poison, provided that before taking the poison, or after, they drink from these cups water, wine, or any other liquor. After some other particulars, Ctesias describes these animals as very swift and very strong. (Ctesias, ed. Bähr, pp. 255, 329, 363.)

Aristotle notices the Indian Ass as a solipede which has a horn, and the only one of the solipedes possessing an astragalus. ('Hist. Anim.,' ii. 1.) He adds, in the third book, on the parts of animals, that those beasts which have only a single horn have it in the middle of their head; and evidently speaks of the Indian Ass from the accounts of others.

Herodotus (iv. 191) mentions asses (ὄνοι) having horns; and Strabo (xv., p. 1009, Oxford, folio) refers to Unicorn horses with the heads of deer.

Oppian ('Cyneget.,' ii., line 96) notices the Aonian bulls with undivided hoofs and a single median horn between their temples, whereas the Armenian bulls have two.

Cæsar ('De Bello Gallico,' vi. 26), when referring to the multitude of animals bred in the great Hercynian forest, speaks, probably from hearsay, of an ox with the figure of a deer, from the middle of whose forehead a single horn stands out higher and more direct than any horns known to him. He adds, that from the top of this horn branches like palms are diffused, that the nature of the male and female is the same, and that the form and size of their horns are similar. He then notices the Elk.

Pliny, who, to be sure, places it in the company of the *Mantichora*, the *Catoblepas*, and the *Basilisk*, notices it as a very ferocious beast (asperrimam feram), similar in the rest of its body to a horse, with the head of a deer, the feet of an elephant, the tail of a boar, a deep bellowing voice (mugitu gravi), and a single black horn, two cubits in length, standing out in the middle of its forehead. He adds, "Hanc feram vivam negant capi," "that it cannot be taken alive" ('Nat. Hist.,' viii. 21); and some such excuse may have been necessary in those days for not producing the living animal upon the arena of the amphitheatre.

Out of this passage most of the modern Unicorns have been described and figured. But let us pause to scan it. The body of the horse and the head of the deer appear to be but vague sketches. The feet of the elephant and the tail of a boar point at once to a pachydermatous animal; and the single black horn, allowing for a little exaggeration as to its length, well fits the two last-mentioned conditions, and will apply to one of the species of Rhinoceros. [RHINOCEROS, in NAT. HIST. DIV.]

Our limits will not permit us to follow out in detail the descriptions of the numerous writers who have treated of this subject, among whom are Ælian, Philostratus, and Solinus, Æneas Sylvius, Marco Polo, Gesner, Cardan, Garzias ab Horto, Andreas Marinus, Andreas Baccius, Bartholinus, Aldrovandus, Jonston, &c. Some, however, of the modern descriptions of the Unicorn may be excepted. Garcias noted down a description of this marvellous creature from one who alleged that he had seen it. The seer affirmed that it was endowed with a wonderful horn, which it would sometimes turn to the left and right, at others raise, and then again depress. Ludovicus Vartomanus writes that he saw two sent to the Sultan from Ethiopia, and kept in a repository at Mahomet's tomb in Mecca, and he describes them as "cancellis obseptos, minimè feroces." Cardan describes the Unicorn as a rare animal, of the size of a horse, with hair very like unto that of a weasel, with the head of a deer, on which one horn grows, three cubits in length (a story seldom loses anything in its progress) from the forehead, ample at its lowest part and tapering to a point; with a short neck, a very thin mane, leaning to one side only, and legs thin as those of a young Roe (capreolus). But, not to weary the reader, if he wishes to see what our ancestors thought Unicorns like, let him turn to Jonston's 'Historia Naturalis' (1657). There he will behold the smooth-horned Solipede ("Wald Esel"), and the digitated and clawed smooth-horned "Meer Wolff," the latter with his single horn erect in the foreground, but with it depressed in the background, where he is represented regaling on serpents. Then there are the smooth-horned "Monoceros, Unicornu, Einhorn," with the head, mane, and tail of a horse, and bisulcate feet; and another smooth-horned "Monoceros, Unicornu, Einhorn," with a horse's head and mane, a pig's tail, and camel-like feet; the "Meer Steinbock, Capricornus marinus," with anterior bisulcate feet, posterior webbed feet, and a kind of graduated horn like a modern flat telescope opera-glass pulled out, in the foreground, and charging the fish most valiantly in the water in the distance; then there is the digitated "Wald Esel, Onager Aldrovandi," with a mule's head and two rhinoceros-like horns, one on his forehead and the other on his nose, and a horse's tail, with a collar round his neck; beneath we find the "Monoceros, seu *Unicornu jubatus*—Einhorn mit mahnen," with a neck entirely shaggy, a twisted horn, anterior bisulcate feet, the posterior being webbed, and a deer's tail; and at the bottom of the plate, "Monoceros, seu Unicornu aliud—Einhorn mit mahnen, ein andr' art" with a twisted horn, mane, and shaggy gorget, curly tail, and camel-like feet.

The Unicorn seems to have been a sad puzzle to the hunters, who hardly knew how to come at so valuable a piece of game. It was however at last discovered that it was fond of rarities, and particularly attached to chaste persons; so they took the field with a virgin, who was placed in the unsuspecting admirer's way. When the Unicorn spied her, he approached with all reverence, couched beside her, and, laying his head in her lap, fell asleep. The treacherous virgin then gave a signal, and the hunters made in and captured the simple beast.

Modern zoologists, disgusted, as they well may be, with fables of which we have only given a specimen or two, disbelieve generally the existence of the Unicorn, such at least as we have above referred to; but the result of M. Guettard's dissertation is an opinion that some terrestrial animal bearing a horn on the anterior part of its head exists besides the Rhinoceros. The nearest approach to a horn in the middle of the forehead of any terrestrial mammiferous animal known to us is the bony protuberance on the forehead of the Giraffe [GIRAFFE, in NAT. HIST. DIV.]; and, though it would be presumptuous to deny the existence of a one-horned quadruped other than the Rhinoceros, it may be safely stated that the insertion of a long and solid horn in the living forehead of a horse-like or deer-like cranium is as near an impossibility as anything can be.

The "Monoceros horne" in Tradescant's collection was probably that which ordinarily has passed for the horn of the Unicorn, namely, the tooth of a Narwhal. Old legends assert that the Unicorn, when he goes to drink, first dips his horn in the water to purify it, and that other beasts delay to quench their thirst till the Unicorn has thus sweetened the water. The Narwhal's tooth makes a capital twisted Unicorn's horn, as represented in the old figures. That in the repository of St. Denis, at Paris, was presented by Thevet, and was declared to have been given to him by the king of Monomotapa, who took him out to hunt unicorns, which are frequent in that country. Some have thought that this horn is a carved elephant's tooth. There is one at Strasburg some seven or eight feet in length, and there are several in Venice.

Great medical virtues were attributed to the so-called horn, and the price it once bore outdoes everything except the Tulipomania. A Florentine physician has recorded that a pound of it (sixteen ounces) was sold in the shops for fifteen hundred and thirty-six crowns, when the same weight in gold would only have brought one hundred and forty-eight crowns.

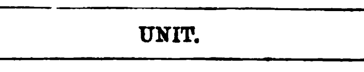
The Unicorn is a national symbol with us, for it is one of the supporters of the royal arms of Great Britain, in that posture termed by heralds "saillant." It was introduced as one of the supporters of the English arms by James I., who having as king of Scotland borne two unicorns, coupled one of them with the English lion on his accession to the throne of England.

UNIFORM. Though this word mean nothing more than "of one form," it has a signification in mathematics which might be better rendered by "of one value" or "of one degree," when we speak to the mathematical proficient. But it is a convenience, though only an accidental one, that the word does not imply the idea of value absolutely; a circumstance which may serve us to elucidate a point of great importance in the differential calculus. The commencement is made in the present article: the continuation will follow in VELOCITY.

In order to understand any application of mathematics, whether to space or matter, it is necessary that a perfect mathematical conception should be formed of the quality of space or matter which is to come under consideration. By a perfect mathematical conception, we mean that it must be distinctly seen, first, that the object under consideration is of the nature of magnitude; secondly, that it is of a measurable kind, that is, is capable of being measured, and can actually have a mode of measuring it assigned. Why do so many persons talk and write vaguely about force, velocity, density, acceleration, &c.? Simply because they are only conversant with the first consideration, and have no precision in their ideas of the second: they feel that they are speaking of magnitudes, of things which they know may be more or less, but they have not that familiarity with the precise way of ascertaining the *how much more* or the *how much less*, without which deduction cannot be made intelligible.

Now we say that in every instance in which measurement is shown to be attainable, there is a notion of uniformity which precedes or ought to precede that of mensurability; and that emphatic mention of this circumstance, and full development of its truth and meaning, ought to be the preliminary step to actual measurement. Moreover, we say that, inasmuch as this idea of uniformity is to be gained previously to that of measurement, we must forego the notion of "uniform" and "of one value" being convertible terms, and illustrate the word by considerations independent of value; for this last term implies measurement, as is easily seen.

If we were to take *velocity* as our instance, most readers would be able to appeal to ideas of measurement and value established in their minds, whether vaguely or precisely: we therefore prefer to choose *curvature*, a term which will be quite new as meaning a measurable magnitude to all except those who have more than an elementary knowledge of mathematics. Curvature is, as the name imports, the bending, the gradual bending, which distinguishes a curve from a straight line. It is a magnitude, that is, it allows of the application of the idea of more and less: one curve may bend more than another, or more in one place than in another. So much every one can be sure of at the first announcement: the next step would be to imagine it possible, that one curve might, say at and about a point A, bend exactly twice as much as another at and about a point B. But here the ordinary reader can only imagine a possibility: no distinct criterion will at once present itself for determining what proportion the bendings or curvatures of two curves are to be stated as having to one another at two given points. If two tangents be drawn at the two given points, it is obvious that, according as the curve bends more or less, there will be more or less deflection from the tangent. Thus the curve A P, at the point A, has as much curvature as A Q, or more; certainly not less. Now as in other cases, if we measure curvature, it must be by curvature, as length by length, weight by weight, &c.: and as a preliminary, it will be desirable to have that curve which has everywhere the same curvature. This curve is obviously a circle, which is throughout its circumference bent in exactly the same manner. Those who cannot imagine how curvatures are to be measured can always see this much, that a true mode of measurement will give the same result to whatever point of a given circle it may be applied. A method of determining value must be false which gives at one point of the same circle a greater curvature than at another. Here we say that any one may see that a notion of uniformity has a useful existence previously to that of any mode of comparing the values of different cases of this uniformity. The circle A may have a radius twice as large as that of B: are we then to say that the curvature of B is double that of A? That the smaller circle bends most is certain; whence it is equally certain that curvature or bending is a magnitude: it has its more and less. Again, it is obvious that the circle B has the same curvature in all its parts, and that the circle A has the same; though the parts of A have a curvature which is not the same as that of the parts of B. Hence it is certain that uniformity of curvature is perfectly conceivable. Now what we have to enforce is, that all this takes place in the mind, before any mode can be given of answering the question how much the curvature of B exceeds that of A. The greater the radius the less the curvature, and A has twice as great a radius as B. If it be proper to say [VARIATION] that the curvature varies inversely as the radius, then B is twice as much curved as A; but if it be proper to say that the curvature varies inversely as the *square* of the radius, then that of B is four times as great as that of A. Here the object of this article ends, and we have referred to VELOCITY the manner of making the next step. At the risk of undue repetition, we state again, that a perfect idea of a magnitude, as a magnitude, and of its uniformity, or total absence of change of value, may exist in cases in which the accurate comparison of values, or measurement, is not attained, and may even exist in a mind which has not the means of conceiving the possibility of such comparison or measurement being accurately made.



UNIGENITUS, BULL. [BULLS, PAPAL.]

U'NISON, in Music, is a sound which is exactly the same as another, in regard to pitch—that is, to acuteness or gravity.

UNIT or UNITY, the name given to that magnitude which is to be considered or reckoned as one, when other magnitudes of the same kind are to be measured. It is not itself *one*, but is the magnitude which *one* or 1 shall stand for in calculation: it is a length, or a weight, or a time, as the case may be, while 1 is only a numerical symbol. This symbol 1 represents the abstract conception of singleness, as distinguished from multitude, and is the unit of abstract arithmetic; but all concrete quantities must have units of their own kind.

Unity, says Euclid (book vii., def. 1), is that according to which each of existing things is called one: *Μονάς ἐστι, καθ' ἣν ἕκαστον τῶν ὄντων ἓν λέγεται.* And, allowing somewhat for idiom, it would not be easy to mend this definition. Anything may be unity, for things of its own kind.

The common division of units into abstract and concrete is merely the distinction between the unit of numeration and that of measurement: the former implying that reckoning or computation is to be performed, without specific reference to any particular object of reckoning; the latter, that some certain unit of length, of capacity, or whatever it may be, is to be signified by 1. On this point the learner must take pains to see, that of all the fundamental operations of arithmetic, three are wholly independent of this distinction, which cannot be said of the fourth. Addition, subtraction, and division can be physically performed, and without reference to units: two lines may be put together into one line, a line may be cut off from another, or a line may be carried along another time after time, until it is seen how many times the greater contains the less. But multiplication requires that number or magnitude should be taken a number of *times*, and the idea of multiplying a magnitude by a magnitude involves an absurdity. [MULTIPLICATION; RECTANGLE.] Nevertheless some enterprising writers on arithmetic profess to multiply magnitude by magnitude; and, to make their doings more striking, they often choose for their instance to multiply *99l.* 19*s.* 11¾*d.* by *99l.* 19*s.* 11¾*d.* To take a humbler case, let us examine the product of 5 shillings and 3 shillings: beginners educated in the common system of arithmetic are generally loth to part with the idea that this must be 15 shillings.

The common rule of three, as generally stated, and given without proof, is the cause of much of the habit which leads to this unwillingness; and for those who cannot see any difference between 5 shillings taken 3 times, and 5 shillings multiplied by 3 shillings, the examination of a question in this rule will be worth while. Let it be as follows:—If 10 apples cost 7 pence, how much will 30 apples cost? The computer proceeds in this manner:—As 10 apples are to 7 pence, so are 30 apples to the answer required. According to the rule, he multiplies together 7 pence and 30 apples, and produces 210—of what he does not say. They can hardly be simple apples, or pence: probably they are 210 chemical compounds of an apple and a penny. The result is to be divided by the first term, 10 apples: here 210 divided by 10 gives 21, and the apples in the divisor decompose this compound, free it of all its fruit, and leave for the final answer 21 pence. The confusion which is caused by the improper use of the concrete unit can hardly be conceived by any but one who has been used to teaching.

UNIT JAR. [ELECTRICITY, COMMON, col. 801.]

UNIT OF WORK. [WORK, UNIT OF.]

UNITARIAN. This term, in its strict and literal interpretation, denotes simply a believer in one God; and, when thus understood, is a generic term, applicable to all Christians, for they all profess to receive the unity of the divine nature; and not only so, but to Jews and Mohammedans also, and even to those unbelievers commonly called Deists, who, on the grounds supplied by natural reason alone, admit the existence, providence, and moral government of one Supreme Being. But it is more commonly understood as opposed to Trinitarian, and is accordingly the received denomination of those Christians who acknowledge one God in one person, as distinguished from those who conceive of him in three persons, characters, or relations, each of which they regard as the proper object of a distinct and separate religious worship. The Unitarian Christian believes the Father to be the only true God, and Jesus his messenger to be the Christ. (John xvii. 3.) This is the leading fundamental principle, which constitutes the true and complete definition of the term; under which are consequently included all those who, receiving the divine authority or commission of Jesus Christ, believe him to be a dependent creature, deriving his existence from the Father, and therefore as the fit object of all the veneration, submission, and obedience which can be offered to a creature, but not of religious worship properly so called. Agreeing in this great and leading principle, Unitarians differ in their opinions as to the origin, nature, and dignity of the author of their religion. Some believe him to have been a celestial spirit of great power and dignity, existing before all worlds, and employed by the Father as his instrument or agent in the creation of the universe, or at least of this portion of it in which we dwell. These are usually called, and call themselves, Arians; though differing in various particulars from the distinguishing tenets of that celebrated heresiarch. Of this class was the late Dr. Price, and many of the principal English Unitarians in the earlier part of the last century. Others believe Jesus to have had no existence previous to his birth, and to have been simply "a man, approved of God by miracles and wonders and signs which God did by him." (Acts ii. 22.) These are not unfrequently styled Socinians: but they themselves, almost universally, reject this appellation; both because it is usually given as a term of reproach (though in fact there is no more reason why it should be so considered than Lutheran, Calvinist, or Arminian), and also because Socinus held certain opinions which they disapprove, particularly the duty of praying to Christ, contrary, as many of them think, to his own express injunction. (John xvi. 23.) Unitarians believe that in Christ dwelt all the fulness of the Godhead, inasmuch as the spirit was not given by measure unto him, and as he was invested with full power to make known to the children of men the will and intentions of God concerning them; and they require no other evidence than his authority for receiving all which he delivered as coming from God. On this authority they believe that there will be a resurrection from the dead, both of the just and of the unjust, when all shall be rewarded according to their works, and when Christ himself shall come in the glory of his Father to judge the living and the dead. They believe that the truth of this declaration was ascertained and exemplified by his own resurrection from the grave. They believe that he was sent to include both Jew and Gentile in the terms of a new and better covenant: and to admit the whole race of mankind to a participation in the privileges of the family of God. For this reason it is that the death of Christ is described by himself as the blood of the new covenant, shed for many for the remission of sins; and hence Unitarians receive him not as God himself, but as the *image* of God (2 Cor. iv. 4), and a ray of his Father's glory—as the one Mediator between God and man.

Unitarians believe in the Atonement; understanding that term in the sense in which it is used in the only place where it occurs in the New Testament, namely, reconciliation. Men were enemies to God by wicked works; they were reconciled by the death of Christ, that is, by the new covenant of grace and mercy ratified by his death, in as far as they have been reclaimed from sin to a life of righteousness. In this sense they think that Christ died *for* us; not in our stead, but on our behalf; to procure for us the benefit of a new and better dispensation. Thus the terms or conditions of salvation are "repentance towards God and faith in the Lord Jesus Christ." And they deny that these views are liable to the charge which is sometimes brought against them, of underrating the evil of sin; considering that by repentance is meant not merely sorrow for past sin, but a change of mind and heart, leading to future amendment, and, when practicable, to restitution.

Unitarians are sometimes charged with relying upon their own merits, but erroneously. They profess to look for everything they have or can expect solely to the free grace and mercy of God, manifested in the gospel of Jesus Christ. This, and this alone, is the *procuring cause* of salvation, of which conversion where necessary, and repentance and better obedience in all cases, are only the prescribed but indispensable condition; a condition, which they believe that all men are competent to fulfil, by a diligent and conscientious exercise of their natural powers. These powers, and the entire constitution which man inherits at his birth, they believe to be such as his Maker intended them to be, not less capable in their own nature of religious and moral improvement than those of his first progenitor, when cultivated with due care, exercised under an influential sense of the Divine presence, and an habitual application for the Divine protection and blessing promised in the Gospel of Jesus Christ.

Unitarians for the most part believe in the doctrine of Universal Restitution; considering punishment, both here and hereafter, not as the expression of what is called *vindictive* justice, but as the instrument of a remedial discipline, destined ultimately to bring back the sinner from the error of his ways. But it should be observed that on this, as on all other points, it is difficult to give any precise statement; because in fact there does not exist any Unitarian *creed* or standard, which the general body have ever formally recognised as of authority. No Unitarian will allow himself to be held responsible for the opinions maintained by any other, let his talents, eminence, or reputation be what they may.

Without touching on the controversies which have arisen respecting the history of Unitarianism in the primitive church, it may be sufficient for our purpose to observe that it quickly made its appearance among the leading reformers of the 16th century. The fate of Servetus, who was burnt at Geneva for the profession of this obnoxious sentiment, is the foulest blot on the character of Calvin. Several of the most eminent of the Italian reformers of that period were anti-Trinitarians of different degrees, some of whom became distinguished lights and founders of Unitarian churches in distant lands. In this country, during the reigns of Edward VI., Elizabeth, and James I., several persons expiated the offence of this form of heresy at the stake; but the first religious society established in England avowedly on this principle was gathered in the time of the Commonwealth by Biddle, who may therefore be styled the father of English Unitarianism. The Unitarians of the present day in this country are chiefly the descendants and representatives of that branch of the early Non-conformists who received the denomination of Presbyterians; and they are still known by that name, though no Presbyterian form of church-government, properly so called, has ever existed either among them or their predecessors. A smaller body are Baptists; and a few societies now Unitarian originally belonged wholly or partially to the Independent denomination. In the proper sense of the word they are all Congregationalists; inasmuch as every society is a distinct religious community, acknowledging no external control upon earth in spiritual concerns. The census of 1851 gave 229 congregations in England and Wales, and 50,061 attendances on Sunday, March 30.

In the United States of America there are at least four distinct religious bodies who profess anti-Trinitarian opinions:—1. A large portion of the Congregationalist churches in Massachusetts, with a few in the adjoining states of New England, to which may be added churches of the same denomination in several of the principal towns in other parts of the Union. 2. The Universalists, whose leading tenet is the doctrine of Universal Restitution; but who have in general adopted some modification of Unitarianism. 3. A considerable majority of the American Quakers, from whom their orthodox brethren seceded and formed a distinct community. 4. A numerous denomination who call themselves *Christians* by way of distinction, refusing to be enrolled as the followers of any other body.

At Geneva, once the fountain-head and stronghold of Calvinism, Unitarianism prevails; and in Transylvania the descendants of the followers of Socinus, Davides, and others, in the 16th century, still form a numerous community.

In this article no attempt has been made to exhibit the scriptural proofs on which Unitarians are accustomed to rely; still less to give any minute critical examination of the texts usually cited in opposition to their doctrines; but merely to state as concisely and distinctly as possible what those doctrines are. Those who wish to obtain further information on the views of Unitarians are referred (among other sources) to Lindsey's *Apology* and *Sequel*; Lardner's *Letter on the Logos*; Belsham's *Calm Inquiry*; Carpenter's *Unitarianism the Doctrine of the Gospel*; Yates's *Replies to Wardlaw*; and the Doctrinal Discourses of the late Dr. Channing.

UNITED BRETHREN. [MORAVIANS.]

UNITED PRESBYTERIAN CHURCH (OF SCOTLAND). The United Secession Church and the Relief Church, which had existed as separate organisations for a considerable period, formed a junction in 1847, under the designation of the *United Presbyterian Church*. The original secession from the Scottish establishment, which took place in the year 1733, was occasioned by two acts of the General Assembly; the first, passed in 1730, for putting an end to the practice of recording the protests, or reasons of dissent, given in by individual members against the decisions of church judicatories; the other, passed in 1732, providing that in cases in which what is called the *jus devolutum*, or right of the presbytery to nominate to vacant livings in consequence of no qualified person being presented by the patron within six months, came into operation, the presbytery should always appoint the person chosen by the heritors and elders. The act of 1732 was not satisfactory to some members of the church because it did not restore (in the cases in which the appointment fell to presbyteries) the more democratic practice which had been established in 1649, placing the election with the elders, or members of the kirk session, alone.

The clergyman who took the lead in the movement against the acts of 1730 and 1732 was Ebenezer Erskine, then one of the ministers of Stirling, who had the co-operation of his brother, Ralph Erskine, minister of the parish of Dunfermline. [ERSKINE, EBENEZER, in BIOG. DIV.] Fifteen members of Assembly protested against the passing of the act of 1732. As the Assembly refused to record this protest, Ebenezer Erskine, in a sermon which he preached a few months later, as moderator of the synod of Perth and Stirling, denounced the proceeding as arbitrary and tyrannical. Upon this sermon the synod passed a resolution of censure, from which Erskine appealed to the General Assembly; but the sentence was confirmed by that supreme court in 1733, and he was rebuked and admonished at the bar of the house. He protested, three other clergymen adhering to him, against this decision, and declared he would continue the conduct for which he had been censured; upon which the Commission of Assembly was authorised to proceed against the four protesters, and they were suspended in August, 1733, and deposed on the 16th of November following. This sentence of the Commission however was removed by the Assembly of 1734, which at the same time repealed both the act of 1730 and that of 1732. But in the meantime the deposed brethren, having been joined by four other clergymen, had constituted themselves into a separate presbytery, under the name of *The Associate Presbytery*; the eight clergymen continuing to officiate in their several churches as usual, till the affair was once more brought before the Assembly of 1739. Even in that house the motion for proceeding to a sentence of deposition was lost; but they were finally deposed, and their parishes declared vacant by an act of the next Assembly, passed 15th May, 1740, by a majority of 140 to 30.

The Seceders, or Associate Synod, as they called themselves, remained a united body till the 9th of April, 1747, when they split into two on a quarrel about a clause in the oath required to be taken by the burgesses or freemen of some of the burghs in Scotland, declaratory of their profession and hearty allowance of "the true religion at present professed within the realm, and authorised by the laws thereof." The larger division, who held that the oath might conscientiously be taken by Seceders, kept the name of the Associate Synod, but were popularly designated Burghers; while those who held that it would be wrong to take the oath took the name of the General Associate Synod, and were known as Anti-burghers. In 1820 the Burghers and Anti-burghers coalesced again into the United Associate Synod of the Secession Church. In 1847, this body, when it united with the Relief Church, consisted of 24 presbyteries, representing about 400 congregations.

The practice of subscribing the Solemn League and Covenant was made imperative upon all members of the Secession by the Associate Synod in 1744; but fell into desuetude after a few years. One chief cause of this was the growth among the Seceders of opinions adverse to the principle of national religious establishments altogether, a principle strongly maintained, and placed on very high ground, in the Covenant. But this change of sentiment subsequently gave rise to the separation of small sections from both divisions of the body who, adhering to the principle of an established church, called themselves Original Seceders, on the ground that the first Seceders from the Established Church held that principle. The members of these sections were known as Old Light Burghers, and Old Light Antiburghers. [SECEDERS.]

The *Relief Church* originated in the secession of a clergyman, Mr. Gillespie, from the Established Church in 1752, on a question of church patronage. Mr. Gillespie did not, for a considerable time, attempt to form any separate ecclesiastical organisation, but kept on friendly terms with many ministers and members of the establishment who sympathised with his views. Others who left the establishment for similar reasons erected places of worship, which were known as Relief Churches, because affording relief from the grievances of lay patronage in the Established Church. From these scattered congregations at length arose several Presbyteries, constituting the Relief Synod. This body, in 1847, at the time of its junction with the United Secession Synod, comprised nine presbyteries, representing 114 congregations.

The United Presbyterian Church now consists of about 550 congregations, constituting 31 presbyteries. The Synod meets annually in May, usually at Edinburgh.

UNIVERSAL; UNIVERSAL AND PARTICULAR (Logic). By a *universal*, in old logic, is meant a term which stands for more things than one: that is, any word which means more than an individual, which applies to a class of objects. In this manner it was applied to the five PREDICABLES, which were also called universals. For the dispute about the character of universals, see NOMINALISTS; but this dispute belongs to metaphysics, not to logic.

The distinction of universal and particular, as applied to propositions, uses the word universal in a different sense. A proposition is *universal* when it makes its assertion or denial about every one of the things spoken of; and *particular* when it makes such an assertion or denial of some as implies that others are, or may be, left unspoken of. Thus "all men are mortal" is universal, and also "no man is perfect." But "some men are born in England" and "some animals cannot live in this climate" are particular. These are the direct logical forms, but it happens commonly that the universal and particular characters are expressed by a great variety of idiomatic turns, and even that forms of expression which, literally speaking, imply universality, are used in a particular sense. Thus "men do not willingly abandon life" strictly means that all men are unwilling to quit life: nevertheless it would be generally understood to speak of most men—all but a few. Except when speaking of laws of nature or necessary conditions of the mind, few writers have much occasion for universal propositions, and consequently the forms of speech which belong to *all*, pass into use when the proposition is intended to be predicated only of *most*.

The particular proposition, in its pure logical form, is of no very common occurrence. The reader must understand that all which is not mentioned is, in the science of logic, considered as unspoken of: now the particular proposition of common life generally denies of the rest what it affirms of some, or affirms of the rest what it denies of some. Thus he who should say "some men are mortal" would be held to utter an untruth, because he would be thought to imply that the rest are not; and a naturalist, wishing to state that some species of a certain animal have fur, in order to state just what his argument requires, would think it necessary to say "some at least," or to use some other form of speech which would signify that, for anything he said to the contrary, all the other species might have fur also. But the logical proposition is always understood to make all possible admission or allowance as to every matter which is not directly spoken of; and "some men are mortal" means that nothing whatever is either said or implied about the rest.

The most common form of speech perhaps is the one compounded of the two particular propositions, the affirmative and the negative, of which the emphatic part is expressed, and the rest implied. Thus, two men going into a company, the first expecting to see all dressed in mourning, and the second thinking none would be so, would come away expressing the same fact in sentences of very different meaning. The first would say "some were not in mourning," the second would say "some were in mourning," both meaning to say "some were and some were not," but each giving only that part of the assertion which contained the (to him) unexpected fact. It would be desirable that writers on logic should make a closer analysis of the common forms of speech, and a comparison of them with the strict and true logical forms.

The universal proposition includes all cases in which there is nothing left unspoken of, and therefore contains all propositions in which the subject is an individual, or cannot be divided into parts. Thus, "Milton was an Englishman" is as much a universal proposition as "all men are mortal." It was at one time a matter of discussion whether propositions asserting matter of individuals could be properly called universal; but whether this term were applicable or not, it was always seen that the rules of deduction applying to such propositions were precisely those which obtain in propositions about the appellation of which no doubt could exist. But the preceding proposition is not universal because it includes *all* Milton, but because it includes all *Miltons*: that is, all Miltons who can answer to a description which is implied in the word as there used. And if, by the closeness of the implied definition, and the number of conditions which are to be fulfilled, there be left but one of men alive or dead whom it is possible to mean, the proposition is not the less true. Thus, when every A is shown to be B, and every B to be C, it follows that every A is C, even though the description given of A be so close that there can be found but one object answering to it in the world.

And just in the same manner as *all* may, logically speaking, be only one, so *some*, or those which are spoken of as some, may be one only, or several, or nearly all, or even all. Some As are Bs is logically true (such is the convention of the formal part of that science) when there is only one A which is B; and also when every A is B.

If we look at the specific elements of propositions, we find that, while the subject is defined, as to whether it be universal or particular, by the express addition of words, or by an implication which has the same effect, the character of the predicate follows the nature of the proposition, and depends solely upon whether it be affirmative or negative. In all affirmative propositions the predicate is spoken of particularly; in all negative propositions, universally. Thus, "As are Bs" in itself does not describe the manner in which A is used: it may be some As or all As; but it does particularise the predicate, B. Here As (so many as are spoken of, be it some or all) are Bs; each one of these As is a B, but other Bs may or may not exist, about which consequently nothing is affirmed. "All horses are animals;" all the horses make up as many of the animals as there are horses: under this form the particular character of the predicate is expressed. But if we say "As are not Bs," even though only one A should be here spoken of, yet every B is compared with it and rejected. What is meant is, that "this one A is not any one whatsoever of all possible Bs."

Formal logic, though an excellent exercise, is in some respects a dead letter unless the student take pains to trace the numerous idioms of language in which the affirmative or negative proposition is conveyed. So very nice are the circumstances, frequently of mere position or of context, by which the universal form is distinguished from the particular, that it would be easy to lay down an isolated sentence, of which no one should be able to say which of the two it is. For example, "homicides are justifiable which are committed in self-defence," and "homicides which are committed in self-defence are justifiable." Though probably the leaning of a grammatical critic would be to the supposition that the first should stand for "All justifiable homicides are those which are committed in self-defence," and the second for "Among the justifiable homicides are," &c., yet no person would be sure of an author's meaning, whichever of the preceding forms he might use, until he had examined the context.

UNIVERSAL DISCHARGER. [Electrical Battery; Electricity, Common.]

UNIVERSAL JOINT. [Hooke's Joint.]

UNIVERSE. This name is generally used, as the word *world* once was, to signify the collection of all created things. In modern language, "the world" generally refers to the earth only, and the universe to all stars and planets. Before the reception of the Copernican theory, "the world," which signifies what we now call the universe, was naturally a synonyme for "the earth," which was supposed to be the principal part of the universe, all the other celestial bodies being only satellites. But since the time when other planets have been advanced to the dignity of being separate "worlds," the term universe has been gradually introduced into common language.

By the technical term *Theory of the Universe* is always understood what is known of the general arrangement of planets, stars, &c., and of their connection with one another.

UNIVERSITIES, lay corporations to which, since the 12th century, the charge of educating the members of what are called the learned professions has in a great measure been confided throughout Europe and the colonies founded by European states. [University.]

The three oldest learned institutions to which the name University can with propriety be applied are those of Paris, Bologna and Salerno.

It is impossible to fix a precise date at which the educational institutions of Paris can be said to have assumed the form and name of a university. As for the name (*universitas*), it was not confined in the middle ages to scientific bodies; it was used in a sense equivalent to our word *corporation*. There were "universities of tailors" in those days. It was long before the name settled down into its present acceptation. The school of Bologna was a "universitas scholarium," that of Paris a "universitas magistrorum," because the former was a corporation of students, the latter of teachers. The oldest printed statutes of the university of Bologna are called "Statuta et privilegia almae Universitatis Juristarum Gymnasii Bononiensis;" and in not a few universities we find an "universitas juristarum" and an "universitas artistarum" side by side: from this it appears that "universitas" at one time approached nearly to the meaning of our word "faculty." What we now term a university was long designated indifferently "schola," "studium generale," or "gymnasium." The occasion of this vacillating nomenclature is explained by the history of universities.

The oldest document in which the designation "universitas" is applied to the university of Paris, is a decretal of Innocent III., about the beginning of the 13th century. But as early as 1180 two decretals had been issued by Alexander III., the first of which ordained that in France no person should receive money for permission to teach. The glossa of Vicentinus says expressly, that this prohibition was directed against the chancellor of the university of Paris; and the second decretal alluded to exempts the then rector, Petrus Comestor, from the operation of the first; and much earlier than any legislative provisions of popes or kings we find the foundations of the university laid.

To almost every cathedral and monastery of Europe there had been, from a very early period, attached a school, in which all aspirants to priestly ordination, and such laymen as wished and could afford it, were instructed in the *Trivium* and *Quadrivium*. It appears from the letters of Abelard (died 1142), and from other contemporary sources, that the poorer establishments intrusted the conduct of this school to one of their number called the Scholasticus; and that the wealthier bodies maintained a Scholasticus to instruct the junior pupils in grammar and philosophy, and a Theologus to instruct the more advanced in theology. About the time of Abelard the great concourse of students who flocked to the episcopal school of Paris appears to have rendered it necessary to assemble the two classes of pupils in different localities; the juniors were sent to the church of St. Julian, while the theologians remained in that of Notre Dame. All who had studied a certain time, and undergone certain trials were entitled to be raised by the rector of the schools to the grade of teachers. This was done by three successive steps. The candidate was first raised to the rank of master, in which he acted for a year as assistant to a doctor (or teacher); then to the rank of baccalaureus, in which he taught for a year, under the superintendence of his doctor, pupils of his own; lastly, to the grade of independent doctor. The number of students rendered the profession of a teacher at Paris lucrative, and many from all nations embraced it. According to the custom of those unsettled times, they gradually formed themselves into a corporation for mutual support. The corporation consisted of the teachers of all the three grades, and stood under a rector elected by themselves. According to an agreement entered into in 1206, the rector was elected by the residents of the four nations—French, English or German, Picards, and Normans. Before this time, in 1200, Philip Augustus had confirmed the exclusive control of the rector over all students and teachers. The local separation of the artists from the theologians would have been of little consequence, but for the rapid progress which the Aristotelian philosophy made during and immediately after the life of Abelard. The speculations into which studious men were led by the writings of Aristotle necessarily brought them to deal with topics which had hitherto been conceived to lie within the exclusive domain of theology. The consequences were frequent and bold attempts by individuals to modify the received doctrines of the church, clamours about heresy, persecutions, and counter-persecutions. All these contributed to bring about a tacit compromise between the professional theologians and the admirers of speculative philosophy: the former were left in possession of the pulpit and chairs of theology; the latter confined themselves ostensibly to literature and philosophy, and sought to avoid occasioning scandal by rarely overstepping the bounds of abstract inquiry. The progress of this tacit agreement may be traced in the writings of the learned from the time of Abelard down to that of Erasmus; under it grew up a class of literati, who may be called, although many of them took orders, secular scholars. It was the same incompatibility of the free spirit of speculative inquiry with the stability of a dogmatic theology which led to this compromise, that embittered the dispute about the claim of the mendicant orders to establish chairs of theology in the University of Paris about the middle of the 13th century. This controversy ended in the secession of the doctors of theology from the university, as it had for some time been called, and their incorporating themselves into a separate college or faculty. Their example was followed not long after by the doctors of canon law and medicine, who formed themselves into separate faculties. These faculties consisted exclusively of the actually teaching doctors (doctores regentes) of these three branches of knowledge. The masters and bachelors remained members of the university proper, which, from the secession of the theologians, canonists, and doctors of medicine, came in time to be called the Faculty of the Artists. From this period the university consisted of seven bodies or sub-incorporations—the four nations under their procurators, and the three faculties under their deans. The rector was the head of the university; he was elected by the procurators of the old university; no doctor of theology, canon law, or medicine could be elected or take part in the election. At first the rector was chosen by the procurators, but latterly by four electors, specially elected by each nation for that purpose. The Prevôt of Paris (so long as that officer retained any authority) was the conservator of the royal privileges in the university; the bishops of Meaux, Beauvais, and Senlis, of the papal privileges. In respect of criminal jurisdiction, the university stood immediately under the king, till A.D. 1200, when its members were transferred to the episcopal court of Paris: about the middle of the 15th century they were transferred to the Parliament of Paris. In regard to civil jurisdiction the University was originally under the bishop; in 1340 it was transferred to the court of the Prevôt of Paris; when the Chatelet succeeded to the judicial functions of the prevôt, the university was transferred to that court. The rector, with the procurators and deans, formed a court, which had jurisdiction in all complaints against teachers for incompetency or neglect of duty; and against students for disobedience to their teachers, the rector, or the discipline of the university, and in all cases between students, lodging-keepers, booksellers, stationers, &c. From the decisions of the rectorial court there was an appeal to the university, and from it to the Parliament of Paris. Each faculty (that of the artists included), had its own common school. In the faculty of canonists, there were six professors (or doctores regentes); the number in the other faculties varied. At an early period colleges were established within the University of Paris by private families or religious orders. Originally they were intended exclusively for poor scholars, who were to live in them subject to certain rules of discipline. By degrees, however, as more numerous and able teachers were employed in these colleges, they assumed the character of boarding-houses for all classes of students. In the 15th century the students who did not reside in any college, had come to be regarded as exceptions from the general custom, and were nicknamed "martinets." The college of the Sorbonne (founded in 1250) was commonly regarded as identical with the theological faculty, because the members of the one were most frequently members of the other also. The promotions however continued to be made by the officers of the university, although the charge of education had been in a great measure engrossed by the colleges. Degrees were conferred in the faculties of theology, canon law, and medicine, by the deans, with the concurrence of the chancellor of the Cathedral of Notre Dame; in the faculty of artists, by the rector, with the concurrence either of the chancellor of Notre Dame or the chancellor of St. Geneviève.

The oldest authentic document bearing upon the University of Bologna is the privilege granted by the emperor Frederic I., at Roncaglia, in November, 1158, to all who travel in pursuit of learning, in which the professors of law are mentioned in terms of high encomium. Bologna is not named in this instrument, but history mentions no other law-school as existing at that early period. The contents of this privilege are twofold; foreign scholars are declared to stand under the emperor's immediate protection, and a special jurisdiction (their teachers, or the bishop of the city) is constituted to judge in all complaints against them. It seems universally admitted that the earliest teacher of civil law at Bologna was Irnerius: he is said to have been originally a teacher of philosophy, but to have acquired such a knowledge of Justinian's compilations that he was invited by the Countess Matilda to expound its doctrines from the professorial chair. Matilda died in 1115: between 1113 and 1115 the name of Irnerius appears in a legal document as "causidicus" for the countess. From 1116 to 1118 he appears to have been employed in weighty missions by the emperor Henry V. Under the emperor Frederic "the four doctors" of Bologna were selected to investigate the rights of the crown, in order to determine how far those claimed by the Lombard towns were usurpations. These circumstances show that the reputation for legal knowledge acquired by the law-teachers of Bologna had proved an introduction to state employments, honours, and emoluments; and this attracted to the city in which they taught a large concourse of the most intelligent and aspiring minds of Europe. The reputation of having studied at Bologna was a passport to office throughout Christendom. The earliest statutes and charters of the University of Bologna are compacts entered into by the students for mutual support and assistance, and immunities granted them by the popes and emperors. The University of Paris was originally an association of teachers: it was a corporation of graduates. The University of Bologna was originally an association of students who had repaired from distant lands to avail themselves of the instruction of a few celebrated teachers: it was a corporation of students. Disputes between the magistrates of the city, and between the students and professors, which occurred about 1214, are the first occasions on which we hear of a rector. From the history of these controversies it appears that the students had previously been in the habit of electing the rector, and that the right was confirmed to them for the future. At first there was merely a school of law in Bologna, and the jurists constituted the university, or rather the two universities of the Citramontani and Ultramontani. In course of time teachers of philosophy and medicine settled in Bologna, and the scholars of each class attempted to form a university: their right to do so was successfully contested by the jurists in 1295, but in 1316 they were allowed to elect a rector of their own. They called themselves "philosophi et medici," or "artistæ." In 1362 Innocent VI. founded a school of theology at Bologna. From this time therefore there were four universities in Bologna: two of law (which, however, were so intimately connected, that they are generally spoken of as one), one of medicine and philosophy, and one of theology. Each of these had its own independent constitution. That of the law university is best known, and agrees in its leading features with the others. The "universities" consisted of the foreign students, who were admitted upon the payment of twelve soldi entry-money, and obliged to renew annually their oath of obedience to the rector and the statutes of the university. The Bolognese students could neither hold offices in the university nor vote in its assemblies. The foreign students were divided into Citramontani and Ultramontani: the former were divided into seventeen nations, the latter into eighteen. The rector was chosen annually from among the students by his predecessor in office, the rector's council, and a number of electors chosen by the nations. A rector was taken from each nation in rotation. The council consisted of at least one representative of each nation: some had two. The university also elected annually a syndic, to act for them in courts of law; a notary; a massarius, or treasurer (chosen from among the town bankers); and two bidelli. The rector claimed exclusive jurisdiction in all civil cases in which one or both of the parties were students, and in criminal cases in which both were students. The professors were elected by the students, to whose body they were reckoned, and all whose privileges they enjoyed, except a vote at elections. They stood under the jurisdiction of the rector, who could fine or suspend them. The degree of Doctor was conferred by those who had previously obtained it: it was held to confer the privilege of teaching everywhere, the power of discipline over the doctor's own pupils, the right to take part in the conferring of all the degrees. At first there were only doctors of civil law: the doctors of canon law appear later, and were long less respected. In the 13th century the university began to create doctors of medicine, of grammar, of philosophy and arts, and even of the notarial art. Any student who had studied five years might be licensed by the rector to expound a single title, or, if he had studied six years, to expound a whole book of the Pandects. He was termed a licentiate; and after he had performed his task, he was declared a baccalaureus. Salaried professors appear in Bologna for the first time about 1279. The doctors taught in their own houses or in halls hired for the purpose: their method of tuition was by lectures, examinations, and disputations.

The history of the University of Salerno is much more obscure than the histories of the Universities of Paris and Bologna. Ordericus Vitalis, whose annals close with the year 1141, speaks of Salerno as a place long eminent for its medical schools. Its most celebrated teacher, Constantine of Carthage (died 1087), was a privy councillor of Louis Guiscard. This school was still flourishing in 1224, when the University of Naples was established. All that can be inferred from these scanty notices of the school of Salerno is, that the scientific study of medicine was making rapid strides about the same time that law began to be more systematically studied, and philosophical and literary pursuits to be regarded as the profession of a class whose members might or might not be priests. [SALERNITANA SCHOLA, in BIOG. DIV.]

A sense of the advantages of general knowledge had led to the foundation of cathedral and cloister schools; a sense of the use of accomplished professional men led to the encouragement of the philosophical and theological schools of Paris, the law school of Bologna, and the medical school of Salerno. The peculiar constitution of society and government at the period led to the peculiar form of incorporation adopted by the schools of Paris and Bologna. The same social necessities were working under the influence of similar social organisation in many different places, and must necessarily have led, even without communication, to similar results. But quarrels which broke out repeatedly between the universities of Paris and Bologna and the civil authorities of these cities, induced the teachers and students at different times to emigrate in a body and settle in other towns. After the breach was healed, they returned; but in some instances celebrated teachers preferred remaining in their new place of settlement, and in others the government created a new university after their temporary visitors had left them. Other universities owed their foundation to the desire of princes, ecclesiastics, or municipal authorities to disseminate learning; and others to a desire on the part of these authorities to procure for their territories a share in the wealth diffused by the resort of numerous foreigners to any celebrated school. Under the influence of motives so various, the growth of universities throughout Europe was rapid. Before the Reformation they were established in many of the principal cities of Italy, France, the Germanic Empire, the Peninsula, Great Britain, and even among the Slavonic nations east of the Germans. In Great Britain the dates of foundation were:—Oxford, before 1149; Cambridge, uncertain; St. Andrews, 1412; Glasgow, 1454; Aberdeen, 1494; Edinburgh, 1582; and Dublin, 1591, are of subsequent foundation.

In all of these institutions we recognise the leading features of Paris or Bologna. All of them, apart from the consideration of their academic character, were privileged corporations, with an independent jurisdiction more or less limited, and the power of making bye-laws. In most of them the division of the members of the corporation into nations prevailed. In all of them the faculties of philosophy (or arts), theology, law (civil and canon), and medicine were more or less fully developed. Some contained within them all the faculties; some only two or more. Almost all had a faculty of arts, which, even where it was politically the most powerful (as in the university of Paris), was regarded as in a great measure preparatory to, and therefore in its scientific character inferior to the others. In the universities of spontaneous growth the privilege of conferring degrees appears to have been claimed only in those faculties which were completely organised; in the factitious universities created by governments the right of bestowing degrees in all faculties appears to have been claimed, even where some of them only were completely organised. In some of these bodies the students constituted the corporation; in others, the masters or teachers: the former appear to have assimilated themselves to the model-university of Bologna; the latter, to that of Paris. The Italian universities, and the greater part, if not all, of the French universities, except Paris, were corporations of students. The Parisian institutions were adopted in England, the Germanic Empire, and the states on the Baltic. Spanish universities have the appearance of being a compromise between the two principles: in Salamanca the rector was elected by the scholasticus of the cathedral from among the students, and the rector appointed the professors and fixed their salaries. This division of the old universities into two classes appears, like everything about those institutions, to have had its origin in the social necessities of the time and countries. The legal faculty predominated in the Italian universities, and the French universities were called "universités des loix." The universities of this type will be found to predominate in those countries in which the Roman law prevailed, as contradistinguished from Teutonic Germany and England, and the "pays coutumiers" of France—in the countries in which the old Roman civilisation had never been entirely extirpated, as contradistinguished from those in which the Teutonic invaders formed the majority of the population. In the former there was a civilisation apart from the church; in the latter there was no civilisation but what came through the church. In the former a secular and independent spirit prevailed: the universities were incorporations of grown men seeking secular learning. In the latter a spirit of clerical domination prevailed: the universities were corporations of teachers seeking to exercise the functions of missionaries.

The universities founded after the beginning of the Reformation adopted the great outlines of the organisation of their predecessors:

the political incorporation, the privileged jurisdiction and power of making bye-laws, the faculties and modes of conferring degrees which custom had established. But the altered circumstances of society modified considerably their external relations. The territorial divisions of Europe had come to be more sharply defined, and the authority of the sovereign to be more energetically enforced by more perfect civil and military organisation. The day of feudal lords, of municipalities and other privileged corporations, each standing upon his or its defence, and acknowledging a limited and precarious subjection to the nominal liege, was past; the day of great states, of territorial governments, had come. The same political power could not and would not be conceded to universities that had formerly been given to them. The old were restricted in their privileges; the new never received them. The protracted strife between the Romish and Protestant churches also had its effect: universities, though no longer allowed to lay down the law, were cherished as advocates of a party. Roman Catholic and Protestant universities were erected to do battle for their respective creeds. Lastly, other sciences had had their practical utility recognised, in the same way as the sciences of law and medicine had had theirs at an earlier period. The application of mathematical science to the purposes of war and navigation had given an impetus to their cultivation: these new practical pursuits never produced a new faculty, but they lent greater importance to the miscellaneous faculty known as the faculty of arts.

The number of universities founded in Europe from the time of the Reformation down to the French Revolution was considerable. But many events occurred during this period to lower universities in the public estimation. The extension of elementary and secondary schools had raised the standard of education among the classes which did not receive a university education. The invention of printing, increasing the facilities of private study, had operated in the same direction. The diminished privileges and restricted jurisdiction of universities had brought them to be regarded merely as schools of a higher order. The increasing number of learned societies raised up a body of non-academical literati, hostile in many instances to the academical; and the public, looking only to the transactions of these societies, forgot that their members were indebted for their training to the universities. Amateur dabblers in science undervalued these institutions; and, in the feverish spirit of innovation which occasioned or accompanied the French Revolution, they too were denounced. In France the old universities have entirely disappeared. In the rest of Europe, as soon as the storms of the Revolution were passed over, they revived; and adapting themselves more to the social necessities of the age, have in many instances started with increased energy on a fresh career of utility. In England two new universities, London and Durham, have been constituted, great improvements have been made in those of Oxford and Cambridge, and further reforms are about to be introduced, as well as into the universities of Scotland.

In the United States of North America the medical and legal professions are educated principally in distinct schools; and this is in the latter country the case also in a great measure with the students of theology. The colleges or universities contain therefore in general only a faculty of arts.

UNIVERSITY. This word is the English form of the Latin *universitas*, which is often used by the best Latin writers. The adjective "universus" signifies the whole of anything, as contrasted with its parts; the plural "universi" also is often used to express an entire number of persons or things, as opposed to individual persons or things. The uses of the word universitas may be derived from the meaning of universus. The word universitas applies either to a number of things, or of persons, or of rights, viewed as a whole. The Roman jurists expressed by the term "universitas bonorum" the whole of a property as contrasted with the parts (singulæ res) which composed it. Such a universitas might be the object of a universal succession, a term which signified the immediate passing from one person to another of all that could be comprehended under such a universitas of property. The Roman hereditas is an instance of such universal succession.

Rights and duties are properly attached to individuals as their subjects: but a number of individuals may be viewed for certain legal purposes as one person or as a unity. Thus the notion of a number of persons forming a juristical person, or a universitas, obtained among the Romans, and universitas was a general name for various associations of individuals, who were also indicated by the names of collegia and corpora. The essential character of these universitates of persons, viewed as juristical persons, was the capacity of having and acquiring property. The property, when had or acquired, might be applied to any purposes which the nature of the association required: but it was the capacity of the association to have and acquire, like an individual, that was the essential characteristic of the body as a universitas; and the purposes for which the property might be had or acquired were no more a part of the notion of a universitas, than the purposes for which an individual has or acquires property are part of his capacity to have or acquire.

The universities or corporate bodies at Rome were very numerous. There were corporations of bakers, publicani or farmers of the revenue, of scribæ, and others. The name was also applied in the sense above explained to civitates, municipia, and respublicæ; and also to the component parts of them, as curiæ, vici, fora, conciliabula, and castella.

From the Roman words universitas, collegium, corpus, are derived the terms university, college, and corporation of modern languages; and though these words have obtained modified significations in modern times, so as not to be indifferently applicable to the same things, they all agree in retaining the fundamental signification of the terms, whatever may have been superadded to them. There is now no university, college, or corporation which is not a juristical person in the sense above explained: wherever these words are applied to any association of persons not stamped with this mark, it is an abuse of terms which requires no further comment.

The word university, in its modern acceptation, has often been misunderstood. Its proper meaning is explained in this article; and the application of the term to associations of teachers or pupils is explained in the article UNIVERSITIES.

UNLAWFUL ASSEMBLY. [RIOT.]

UNLIMITED. This term is frequently used by mathematical writers, in the same manner as INDEFINITE, to avoid the entrance of the word INFINITE. It is also used to describe a problem which may have an infinite number of answers, and which is called an unlimited problem.

UNSTABLE EQUILIBRIUM. [STABLE AND UNSTABLE; STABILITY.]

UPAS POISON. [ANTIARIN.]

URAMIL. [URIC GROUP.]

URAMILIC ACID. [URIC GROUP.]

URANIC ACID. [URANIUM.]

URANIUM (U), a metal discovered by Klaproth, in 1789, who named it after the planet Uranus, the discovery of which had occurred in 1781: the mineral from which it was first obtained is called *pechblende*, which contains about 80 per cent. of the black oxide of uranium ($2UO, U_2O_3$). This and other minerals from which uranium is extracted are described in the NATURAL HISTORY DIVISION of this Cyclopædia.

M. Péligot obtains this metal by decomposing its chloride by means of potassium or sodium, a process which has been successfully adopted for procuring aluminum and magnesium: the metal so separated is partly in the state of a black powder, and partly agglomerated; by carefully detaching the portions which adhere to the sides of the crucible, plates of a metallic lustre comparable to that of silver, are obtained; these are susceptible of being filed, but possess a certain degree of malleability, and have evidently undergone incipient fusion. Uranium is very combustible; at a moderate degree of heat, in contact with the air, it burns with a remarkably white and shining light; the combustion occurs at so low a temperature, that it may take place on paper without causing it to burn. If small particles be shaken from the filter on which the metal in powder has been collected, portions so minute as to be scarcely visible burn with brilliant sparks on coming near the flame of a candle. When heated in a capsule, uranium burns brilliantly, and is converted into a deep green-coloured oxide, the bulk of which is considerably greater than that of the metal employed.

Uranium does not appear to suffer any alteration by exposure to the air, nor does it decompose water at common temperatures, but when put into diluted acids it dissolves in them with the evolution of hydrogen gas. It somewhat resembles iron and manganese in its chemical character. Its equivalent number is 60.

Having now described the properties of uranium we proceed to consider the compounds which it forms with other bodies.

Oxygen and Uranium.—According to M. Péligot, there exist, or may be formed, three oxides of uranium: the protoxide, formerly considered as metallic uranium; that prepared by calcining the nitrate, known by the name of deutoxide of uranium, or uranous acid; lastly, the peroxide, uranic acid, which enters into the composition of the yellow salts. Besides these oxides, it is stated, by the chemist above named, that there are two suboxides of uranium produced by the decomposition of the subchloride by ammonia, and an oxide intermediate between protoxide and peroxide of uranium, which is formed when the oxide obtained by calcining the nitrate is submitted to the action of oxygen.

Suboxide of Uranium (U_4O_3). When ammonia is added to a solution of subchloride of uranium a brown precipitate is formed, which undergoes various changes of colour and composition by absorbing oxygen. Its extreme instability renders its analysis very difficult. It decomposes water, to combine with its oxygen to form the apple-green suboxide, the analysis of which is equally difficult.

Protoxide of Uranium ($U\,O$), formerly regarded as metallic uranium. This may be prepared by several processes; one of the best consists in decomposing the yellow oxalate of uranium by hydrogen: the process requires several precautions. Prepared in this manner the protoxide is extreme pyrophoric, the access of air causing it to burn with feeble incandescence and converting it into black peroxide: it is of a cinnamon-brown colour. When the protoxide of uranium is obtained by reducing the double chloride of potassium and uranium, not by means of hydrogen, it is obtained in crystalline scales possessing a high degree of lustre, and being then in a higher state of aggregation it is not pyrophoric; and when procured by decomposing the nitrate, the protoxide is of a maroon colour. When thus prepared in the dry way, it is not acted upon either by hydrochloric or sulphuric acid when diluted; but dissolves in the latter, when concentrated: nitric acid also dissolves it, but nitrate of peroxide of uranium is obtained.

This oxide may likewise be obtained in the moist way, and then it is soluble in dilute acids: it is precipitated in the state of hydrate, by adding ammonia to the green solution of chloride of uranium; the precipitate is of a reddish-brown colour, which by ebullition becomes black and dense, probably because it is dehydrated. It may also be procured by putting fragments of marble into the green solution of chloride of uranium.

Black Oxide of Uranium ($2UO, U_2O_3$) is obtained by calcining the nitrate at a high temperature. It is not decomposable by heat; when added to acids they do not directly combine with it, but a mixture of salts of the protoxide and peroxide is formed.

Olive Oxide of Uranium (UO, U_2O_3).—When any of the preceding oxides are submitted at a low red heat to the action of oxygen, the olive-coloured oxide is formed. It has a velvety appearance, and when strongly heated it loses oxygen and is converted into the black oxide, and when acted upon by acids there is formed a mixture of yellow and green salts, in which the salts of the peroxide exist in the larger proportion, and this is an advantageous process for preparing them.

Peroxide of Uranium, or Oxide of the Yellow Salts (U_2O_3).—This oxide, which is of all the most important, is obtained with difficulty in a separate state: when nitrate of uranium is decomposed with a gentle heat, an orange-coloured subsalt remains, which by the application of a stronger heat becomes olive and then black oxide; when an alkali is poured into a saline solution of this oxide, the yellow precipitate formed retains alkali in combination; even uranate of ammonia resists the prolonged action of boiling water and also of a vacuum; by heat the ammonia and water are not expelled till peroxide itself undergoes decomposition.

Chlorine and Uranium.—The protochloride (UCl) is obtained by passing a current of dry chlorine gas over an intimate mixture of equal parts of any oxide of uranium and charcoal submitted in a glass tube to a high temperature. The chloride of uranium formed appears in the state of a red vapour, and condenses in the cool part of the tube in very regular octohedrons of a metallic lustre, and of a black or green colour according to their size.

Chloride of uranium is volatile, and attracts water so strongly that it very soon becomes fluid by exposure to the air, the moisture of which also decomposes it.

Subchloride of Uranium (U_4Cl_3).—This compound is obtained by passing a current of dry hydrogen gas over the chloride of uranium moderately heated in a glass tube. The residue of this operation is of a deep brown colour, in fine filaments which are but slightly volatile at the temperature at which it is formed: it is very soluble in water; the solution is purple at first, but in a few seconds it becomes green; it gives out hydrogen gas, and at the same time deposits a red powder, which is very probably oxide of uranium, yielded in consequence of the transformation of this substance into chloride of uranium.

Sulphide of Uranium of a black colour may be obtained by adding the alkaline sulphides to solutions of uranium, or by passing the vapour of sulphide of carbon over the oxide at a high temperature.

We shall now briefly notice some of the oxysalts of uranium.

Sulphate of Protoxide of Uranium.—This salt is obtained by adding sulphuric acid to the protochloride of uranium, and heating the mixture, by which hydrochloric acid is expelled, and sulphate of uranium remains; by dissolving the residue in water, and evaporating the solution, green prismatic crystals of the sulphate are formed.

It frequently happens that the crystals possess a silky lustre, are greenish, and but slightly soluble in water; in this case they contain excess of base. This salt yielded by analysis:—

Sulphuric acid	28·0
Protoxide of uranium	46·1
Water	25·9
	100·

Oxalate of Protoxide of Uranium.—This salt is of a greenish-white colour, and very slightly soluble in water either cold or hot. It may be prepared by mixing solutions of oxalic acid and chloride of uranium; the precipitate formed is to be repeatedly washed with boiling water, in order to dissolve the yellow oxalate of the peroxide, which is more soluble, and which is first precipitated. The protoxalate of uranium, after being dried, may be exposed to the air without undergoing any perceptible change.

Nitrate of Peroxide of Uranium ($U_2O_3,NO_5+6Aq.$).—This salt is easily obtained in fine regular crystals. It is of a yellowish colour, effloresces in vacuo, and loses half its water of crystallisation.

Uranium forms a considerable number of double salts, which we have not thought it requisite to describe.

Peroxide of uranium is employed in colouring glass, to which it imparts a fine lemon yellow.

URANUS, the next planet beyond Saturn, counting outwards from the sun. This important member of the planetary system was discovered by Sir William Herschel in the year 1781. On the evening of the 13th of March of that year, while examining certain small stars in the constellation Gemini, the attention of the astronomer was drawn to a small star which appeared sensibly larger than those in its vicinity. With the view of testing the object he applied different magnifying powers to his telescope, whereupon he found that the apparent magnitude of the star in question varied in the direct ratio of the magnifying power, while the stars around it when similarly surveyed by him exhibited only a slightly perceptible change of apparent diameter. Suspecting from this circumstance that the object was a comet, he proceeded to make careful observations of its position by measuring its distance from the stars near to it. A few nights only elapsed before he obtained undoubted evidence of the star being in a state of motion. It appeared to be travelling slowly in the order of the signs, in an orbit inclined at a small angle to the plane of the ecliptic. Having continued his observations down to the 19th of April, he then drew up an account of them, and communicated it to the Royal Society in a paper which was read before that body on the 26th of the same month. He appears to have been under the impression that the object discovered by him was no other than a comet.

Attempts were made by various astronomers on the Continent to determine the orbit of the supposed comet, on the hypothesis of its revolving in a parabola with a comparatively small perihelion distance; but it was found impossible to represent the observed motion of the body in this manner, except for a very small arc of the orbit. At length Lexell, in a paper which he communicated to the Academy of Sciences of St. Petersburg, announced certain facts, which seemed to indicate that the object discovered by Herschel was in reality a planet. In the first place, it differed from a comet in being well defined. On the other hand, it did not exhibit the bright piercing light of the fixed stars. But while thus unlike a comet or a star, it exhibited several features which tended to support the idea of its being a planet. It was to be remarked that, like all the planets, it travelled in the celestial sphere in the order of the signs. Again, while it was actually situate near the ecliptic, its motion in latitude was exceedingly small, a circumstance which seemed to indicate that like the planets it revolved in an orbit, confined within the limits of the zodiac. But Lexell obtained still more convincing evidence in support of his suspicion that the object was a planet. Taking two extreme observations of its position, one of them by Herschel, dated March 17, 1781, and the other by Maskelyne, dated May 11, of the same year, he found that they might be well represented by supposing the body to revolve in a circular orbit, the radius of which amounted to 18·93, the radius of the earth's orbit being assumed equal to unity. Astronomers henceforward agreed in supposing that the object discovered by Herschel was in reality a planet revolving around the sun in the region beyond Saturn. It was soon found, however, that a circular orbit was incapable of satisfying the observations, and that the real orbit must be an ellipse of slight excentricity. Laplace, in 1783, first determined the elliptic elements of the planet's orbit, which he communicated to the Academy of Sciences in the same year.

The right of naming the new planet belonged to the discoverer, who proposed to call it the *Georgium Sidus*, as a mark of gratitude to his munificent patron George III., under whose auspices he was enabled to prosecute his astronomical labours. This designation, however, was at variance with the nomenclature hitherto employed in the planetary system, and the name of Uranus, suggested by the German astronomer, Bode, is that by which it is usually designated.

Herschel found by micrometric measures that the apparent diameter of the new planet, when viewed at its mean distance from the earth, amounted to 3″·91. This gave 34,217 miles for the value of its absolute diameter. It was, therefore, after Jupiter and Saturn, by far the most considerable of the planetary bodies hitherto recognised as revolving around the sun.

It appeared from an examination of the recorded observations of Flamsteed and several succeeding astronomers, that Uranus had been observed on several occasions, previous to its actual discovery as a planet in 1781, under the impression of its being a fixed star. These early positions proved exceedingly valuable in enabling astronomers speedily to determine the elements of the orbit with a degree of precision which, from the slow motion of the planet, could otherwise have been expected to result only after the lapse of a considerable number of years. In 1790 Delambre obtained the prize of the Academy of Sciences of Paris for the construction of tables of the planet. These tables were founded on the observations made subsequently to the discovery of the planet in 1781, and on certain earlier determinations of its position. For several years they sufficed to represent the observed motion of the planet with tolerable precision, but eventually discordances became apparent, which continued to increase in magnitude from year to year. In 1821 Bouvard published new tables of the planet. They were based exclusively on the observations made after the discovery of the planet by Herschel, their author having found it impossible to satisfy by means of the same orbit both the earlier and the more modern observations. These tables continued for a few years to represent the motion of the planet with all desirable precision; but they, in their turn, soon began to deviate from the results of observation, and the discordances continued steadily to increase in magnitude. The reader is aware that the study of these irregularities led to the discovery of a new planet beyond Uranus. In a preceding article [NEPTUNE] a detailed account has been given of the circumstances connected with this memorable triumph of science.

The following are the elements of the orbit of Uranus:—

Mean longitude, Jan. 1, 1800	173° 30′ 37″
Longitude of the perihelion	167° 30′ 24″
Longitude of the ascending node	72° 59′ 21″
Excentricity of the orbit	0.0466794
Inclination of the orbit to the ecliptic	46′28″
Mean distance from the sun	19·18239
Time of a sidereal revolution	30,686·8 days
Mass in terms of the sun's mass as the unit	$\frac{1}{17,918}$

There exists some uncertainty with respect to the mass of the planet. The foregoing value was deduced by Bouvard from the observed perturbations of Saturn. Lamont, from the observed elongations of the satellites, has determined the value of the mass to be $\frac{1}{24,605}$. No tables of Uranus have been published subsequently to the discovery of Neptune in 1846. A correct theory of the planet, with tables founded thereon, is still a desideratum in astronomy. It is to be presumed that M. Le Verrier, who is at present engaged in a systematic investigation of the theory of the various bodies of the planetary system, will in due time accomplish this important object.

URANUS, SATELLITES OF. In the beginning of the year 1787 Sir William Herschel discovered two satellites around Uranus. Having made a series of careful observations of their position with respect to the primary, he next proceeded to determine the elements of their orbits. The results of this investigation are contained in a paper which he communicated to the Royal Society in the following year. He obtained for the times of revolution of the two satellites these values:—

	d	h.	m.	s.
Period of first satellite	8	17	1	19·3
Period of second satellite	13	11	5	1·5

He also determined the apparent distance of the second satellite from the centre of the planet to be 44″·23. The first satellite, that is, the satellite next to the planet, was an object of such faintness that he was unable to arrive at a definite conclusion with respect to the apparent distance. He however deduced the value of this element from the periodic times of the two satellites, and the apparent distance of the second, by the aid of Kepler's third law. In this way he found the apparent distance of the satellite to be 33″·09. In a paper which he communicated to the Royal Society in the year 1797, he announced two interesting facts with respect to the movements of those minute bodies. The first was that their motions are retrograde, or, in other words, that their revolutions are effected in a direction contrary to the order of the signs; the second consisted in this, that the orbits of the satellites are nearly perpendicular to the plane of the ecliptic.

In the same paper Herschel announced his discovery of four additional satellites around the planet. This made the aggregate number of satellites revolving around the planet to amount to six. The following values of the periodic time and distance of each satellite were given by him. The distances are expressed in terms of the semidiameter of the planet:—

Order of Distance from the Planet.	Periodic time. d.	h.	m.	Distance from the Planet.
1st satellite	5	21	25	13·120
2nd "	8	17	1	17·022
3rd "	10	23	4	19·845
4th "	13	11	5	22·752
5th "	38	1	49	45·507
6th "	107	16	40	91·008

It will be seen from this table that the two satellites originally discovered by Herschel are the second and fourth, counting in the order of distance from the primary. The periodic times and distances of these satellites were satisfactorily determined by an investigation founded on their observed positions. The case, however, was different with respect to the other satellites. The distance of the first satellite was indeed the result of micrometrical measures, but the distances of the other satellites were mere estimations. The orbit of the third satellite was supposed to bisect the linear interval between the second and fourth satellites; the fifth satellite was supposed to be twice as distant from the planet as the fourth; and the sixth satellite to be twice the distance of the fifth. The periodic times of the four satellites were deduced from these data, and the elements of the second and fourth satellites by the aid of Kepler's third law.

A paper which Herschel communicated to the Royal Society in the year 1815, contains his final researches on the motions of the satellites of Uranus. It appeared from his observations that the planet passed through the common ascending node of the satellites on the 12th of March, 1798. He hence determined the longitude of the node to be 165° 30′. He also obtained 78° 58′ for the inclination of the orbits of the satellites to the ecliptic. On the same occasion he determined anew the synodic revolutions of the second and fourth satellites, which he found to be $8^d\ 16^h\ 56^m\ 5{\cdot}2^s$, and $13^d\ 11^h\ 8^m\ 59^s$ respectively. He still retained his belief with respect to the existence of four additional satellites, and, although he was unable to assign any further proof of a positive nature in support of his opinion, he communicated a series of rough notes of their observed positions which might aid the labours of future inquirers.

In 1828, Sir John Herschel, having directed one of his 20-foot reflectors towards Uranus, succeeded in obtaining a view of the two satellites originally discovered by his father. Having subsequently executed a series of micrometric measures of their observed positions, he instituted a comparison between them and the corresponding results of his father's observations, and in this way he was enabled to deduce new values of the periodic times of the two satellites. He found the period of the second satellite to be $8^d\ 16^h\ 56^m\ 31{\cdot}3^s$, and that of the fourth to be $13^d\ 11^h\ 7^m\ 12{\cdot}6^s$. It will be seen that these results do not differ materially from the corresponding numbers which the elder Herschel derived from his researches. M. Lamont, Director of the Munich Observatory, having in the year 1837 made a series of observations of the same satellites with a refractor of 11 inches aperture, obtained, by a comparison of his own measures with those of the two Herschels, values of the periodic times agreeing very closely with those deduced by Sir John Herschel.

Recently, Mr. Lassell has discovered two satellites revolving within the orbit of Herschel's second satellite, but neither of which appears to coincide with Herschel's first satellite. He has applied to them the names Ariel and Umbriel, designating at the same time the second and fourth satellites of Herschel by the names Titania and Oberon. He does not recognise the existence of any other satellites around the planet except the four to which he has applied these names. The following synopsis may be useful:—

Order of Distance from Primary.	Name of Satellite.	Time of Revolution. d.	h.	m.	s.
1	Ariel	2	12	28	48
2	Umbriel	4	3	27	22
3	Titania	8	16	56	31
4	Oberon	13	11	7	12

URATES. [Uric Group.]

UREA ($C_2H_4N_2O_2$). The essential solid constituent of urine. Containing nearly half its weight of nitrogen, it forms the chief vehicle for the final concentration and elimination of that element from the animal organism. Produced in the blood by the oxidising action of inspired air on albumen and other nitrogenous forms of assimilated food and exhausted tissue, it is removed from the blood by the kidneys, and is finally excreted in the urine.

Urea was first separated from urine in 1773, by Rouelle; in 1779, Fourcroy and Vauquelin isolated it in the pure state. Though now usually prepared for experimental purposes by an artifical process presently to be described, it may readily be procured from urine by the following method. A solution of ammoniacal nitrate of copper is added to urine until no farther precipitation of albumenoid and colouring matter occurs; the mixture is then filtered, the colourless filtrate evaporated to a thin syrupy consistence, and about an equal bulk of strong nitric acid added to it. The mass of crystals of nitrate of urea, thus obtained, are gently pressed between blotting paper which frees them from mother liquor, are suspended in water, carbonate of baryta added so long as effervescence of carbonic acid occurs, the mixture evaporated to dryness, the residue treated with boiling alcohol and filtered, and the filtrate set aside to cool and spontaneously concentrate, when long, slender, colourless, striated prisms of urea crystallise out.

Urea is formed artificially in many reactions. By the action of oxidising agents on uric acid; by the influence of alkalies on kreatine or alloxan; on treating fulminate of mercury or silver with sulphuretted hydrogen; from ammonia and carbonic ether, or ammonia and oxychloride of carbon. A method of greater interest than any of the preceding, inasmuch as it gives experimental demonstration of its mode of formation in the human system, is that by M. Bechamp, who produced it from albumen and other azotised compounds, by the oxidising action of a solution of permanganate of potash at a temperature of 176° Fahr.

But the most convenient and economical process for producing urea artificially, is that in which an aqueous solution of cyanate of ammonia has simply to be heated to near the boiling point, when transformation into urea at once occurs:—

$$\underbrace{NH_4O,\ NC_2O}_{\text{Cyanate of ammonia.}} \quad = \quad \underbrace{C_2H_4N_2O_2}_{\text{Urea.}}$$

This close relationship of cyanate of ammonia to urea was first noticed by Wöhler and Liebig in a research on the cyanates. The following are the details of the process by which the cyanate of ammonia, and ultimately urea, is obtained. Twenty-eight parts of well-dried ferrocyanide of potassium and fourteen of binoxide of manganese are finely powdered and intimately incorporated; the mixture is then spread out on an iron plate, and exposed over a furnace containing a dull red fire. The mass soon undergoes a smouldering combustion, absorbing oxygen from the binoxide and, especially if frequently stirred, from the air. When combustion has ceased the mixture is removed, allowed to become quite cold, is then treated with cold water, filtered, and the residue washed. To the washings twenty and a half parts of sulphate of ammonia are added, and the first filtrate then stirred in. Much sulphate of potash will now go out of solution as a granular precipitate, the potassium of the ferrocyanide having been oxidised during the roasting operation: the cyanogen of the ferrocyanide was, however, also oxidised at the same time and by the same means to cyanic acid, which remains in solution combined with ammonia. Evaporated to dryness over a water-bath the solution of cyanate of ammonia yields dry urea, which is separated from residual sulphate of potash by digesting in hot alcohol, containing not more than 10 or 15 per cent. of water. The alcoholic solution yields, on cooling, colourless crystals of urea to the extent of 33 per cent. of the ferrocyanide of potassium used. Should the solution of sulphate of potash have a yellow colour, it will be due to undecomposed ferrocyanide of potassium. In that case sulphate of iron must be added till prussian blue no longer precipitates, and any excess of iron got rid of by carbonate of ammonia.

Pure urea crystallises in colourless, inodorous, transparent, four-sided prisms. It has a saline taste somewhat like that of nitrate of potash. It is soluble in its own weight of water, and requires five parts of cold alcohol, but only one part of boiling alcohol, to dissolve it: it is less soluble in ether, and insoluble in oil of turpentine. Exposed to the air it becomes somewhat moist; melts when heated to near 250° Fahr., and at higher temperatures yields ammonia, carbonate of ammonia, BIURET and MELANURIC ACID. Solution of urea is stable if pure, but in urine, or in the presence of any decomposing organic matter, the urea rapidly changes into carbonate of ammonia:—

$$\underbrace{C_2H_4N_2O_2}_{\text{Urea.}} + 4HO = \underbrace{2(NH_4O, CO_2)}_{\text{Carbonate of ammonia.}}$$

The same change occurs if solution of urea be heated to 284° Fahr. in a sealed tube. Chlorine produces cyanuric acid from fused urea, but quite breaks up urea in solution: nitrous acid also oxidises it to carbonic acid, nitrogen and water.

Urea combines with acids to form definite salts. The formation of *nitrate of urea* ($C_2H_4N_2O_2$, HO, NO_5) has already been described; it crystallises in bright transparent rhombic plates or leaflets, only slightly soluble in water, alcohol, or nitric acid. *Hydrochlorate of urea* ($C_2H_4N_2O_2$, HCl) is a deliquescent unstable salt, formed when hydrochloric acid is passed into urea. A *subhydrochlorate* ($2C_2H_4N_2O_2$, HCl) crystallises in long transparent blades from a solution containing the proper equivalents of each compound. *Oxalate of urea* ($C_2H_4N_2O_2$, HO, C_2O_3) falls as a crystalline, almost insoluble, precipitate when excess of strong solution of oxalic acid is added to solution of urea; it may be obtained in long, thin, colourless, transparent prisms. It is probable that ALLOPHANIC ACID is *carbonate of urea*.

Urea also combines with metallic protoxides. If freshly precipitated oxide of silver be digested in a strong solution of urea, a yellowish crystalline powder is formed containing (3 AgO, $C_2H_4N_2O_2$). With the red oxide of mercury urea forms compounds containing respectively two, three, and four atoms of mercuric oxide to one of urea. The first (2 HgO, $C_2H_4N_2O_2$) separates out as a white powder from a solution of moist mercuric oxide in urea; the second (3 HgO, $C_2H_4N_2O_2$) is a gelatinous precipitate produced when solution of mercuric chloride is added to solution of urea kept alkaline by potash: it becomes granular and of a pale yellow colour on boiling; the third (4 HgO, $C_2H_4N_2O_2$) is prepared in the same manner as the second, mercuric nitrate being used instead of chloride.

Urea forms compounds with metallic salts. Solutions of urea and nitrate of silver, mixed and evaporated in vacuo over sulphuric acid, yield crystals containing (AgO, NO_5, $C_2H_4N_2O_2$) and ((2 AgO, NO_5), $C_2H_4N_2O_2$). A dilute and warm solution of mercuric nitrate added to a warm solution of urea, gives a granular precipitate containing (4 HgO, NO_5, $C_2H_4N_2O_2$); if the mercuric nitrate be added in excess, and the whole maintained at a temperature ranging from 104° to 122° Fahr., the precipitate occurs in six-sided prisms, and has the composition (3 HgO, NO_5, $C_2H_4N_2O_2$); if the mercuric nitrate be acidulated with nitric acid, and solution of nitrate of urea be added until a precipitate occurs, the filtered solution deposits shining rectangular tables of (2 HgO, NO_5, $C_2H_4N_2O_2$). Double nitrates of urea and soda, baryta, lime, and magnesia have also been obtained.

Compound ureas. As already indicated, urea is formed by combination of ammonia (NH_3) and cyanic acid (C_2HNO_2):—

$$\underbrace{NH_3}_{\text{Ammonia.}} + \underbrace{C_2(H)NO_2}_{\substack{\text{Cyanic acid}\\\text{(cyanate of hydrogen).}}} = \underbrace{C_2(H_4)N_2O_2}_{\text{Urea (ordinary).}}$$

If in the place of cyanic acid—or cyanate of hydrogen as, for the sake of analogy, it may be more conveniently termed—the cyanate of some radical, other than hydrogen, be taken, an urea will be obtained containing the radical of the cyanate used, in the place of one of the four equivalents of hydrogen in common urea. Thus:—

$$NH_3 + \underbrace{C_2(C_2H_3)NO_2}_{\text{Cyanate of methyl.}} = \underbrace{C_2(C_2H_3, H_3)N_2O_2}_{\text{Methyl-urea.}}$$

$$NH_3 + \underbrace{C_2(C_6H_5)NO_2}_{\text{Cyanate of allyl.}} = \underbrace{C_2(C_6H_5, H_3)N_2O_2}_{\text{Allyl-urea.}}$$

$$NH_3 + \underbrace{C_2(C_{12}H_5)NO_2}_{\text{Cyanate of phenyl.}} = \underbrace{C_2(C_{12}H_5, H_3)N_2O_2}_{\substack{\text{Phenyl-urea}\\\text{(carbanilamide).}}}$$

If a sulphocyanate be used, a sulpho-urea will of course be produced:—

$$NH_3 + \underbrace{C_2(C_6H_5)NS_2}_{\substack{\text{Sulphocyanate}\\\text{of allyl.}}} = \underbrace{C_2(C_6H_5, H_3)N_2S_2}_{\substack{\text{Sulphallyl-urea}\\\text{(thiosinnamine).}}}$$

$$NH_3 + \underbrace{C_2(C_{12}H_5)NS_2}_{\substack{\text{Sulphocyanate}\\\text{of phenyl.}}} = \underbrace{C_2(C_{12}H_5, H_3)N_2S_2}_{\text{Sulpho-phenyl-urea.}}$$

And if now in the place of ammonia itself, a derivative of ammonia (monamines, &c.) be acted upon by the cyanate, ureas are formed in which two, three, or even the four equivalents of hydrogen in common urea, are replaced by compound radicals. Thus:—

$$\underbrace{NH_2, C_4H_5}_{\text{Ethylamine.}} + \underbrace{C_2(C_4H_5)NO_2}_{\text{Cyanate of ethyl.}} = \underbrace{C_2(2C_4H_5, H_2)N_2O_2}_{\text{Diethyl-urea.}}$$

$$\underbrace{NH_2, C_{12}H_5}_{\text{Phenylamine.}} + \underbrace{C_2(C_{12}H_5)NO_2}_{\text{Cyanate of phenyl.}} = \underbrace{C_2(2C_{12}H_5, H_2)N_2O_2}_{\text{Diphenyl-urea (flavin).}}$$

$$\underbrace{NH_2, C_2H_3}_{\text{Methylamine.}} + \underbrace{C_2(C_4H_5)NO_2}_{\text{Cyanate of ethyl.}} = \underbrace{C_2(C_2H_3, C_4H_5, H_2)N_2O_2}_{\text{Methyl-ethyl-urea.}}$$

$$\underbrace{NH_2, C_4H_5}_{\text{Ethylamine.}} + \underbrace{C_2(C_6H_5)NO_2}_{\text{Cyanate of allyl.}} = \underbrace{C_2(C_4H_5, C_6H_5, H_2)N_2O_2}_{\text{Ethyl-allyl-urea.}}$$

$$\underbrace{NH_2, C_{12}H_5}_{\text{Phenylamine.}} + \underbrace{C_2(C_4H_5)NO_2}_{\text{Cyanate of ethyl.}} = \underbrace{C_2(C_{12}H_5, C_4H_5, H_2)N_2O_2}_{\text{Phenyl-ethyl-urea.}}$$

$$\underbrace{NH_2, C_4H_5}_{\text{Ethylamine.}} + \underbrace{C_2(C_6H_5)NS_2}_{\substack{\text{Sulphocyanate}\\\text{of allyl.}}} = \underbrace{C_2(C_4H_5, C_6H_5, H_2)N_2S_2}_{\text{Sulphethylallyl-urea.}}$$

$$\underbrace{NH_2, C_{12}H_5}_{\text{Phenylamine.}} + \underbrace{C_2(C_6H_5)NS_2}_{\substack{\text{Sulphocyanate}\\\text{of allyl.}}} = \underbrace{C_2(C_6H_5, C_{12}H_5, H_2)N_2S_2}_{\text{Sulphallyl-phenyl-urea.}}$$

$$\underbrace{NH, C_{10}H_{10}''}_{\text{Piperidine.}} + \underbrace{C_2(C_4H_5)NO_2}_{\text{Cyanate of ethyl.}} = \underbrace{C_2(C_4H_5, C_{10}H_{10}'', H)N_2O_2}_{\text{Ethyl-piperyl-urea.}}$$

$$\underbrace{N(C_4H_5)_3}_{\text{Triethylamine.}} + \underbrace{C_2(C_4H_5)NO_2}_{\text{Cyanate of ethyl.}} = \underbrace{C_2(C_4H_5)_4N_2O_2}_{\text{Tetrethyl-urea.}}$$

Compound ureas are also prepared by the action of water on cyanates of radicals. Thus:—

$$\underbrace{2C_2(C_2H_3)NO_2}_{\text{Cyanate of methyl.}} + \underbrace{2HO}_{\text{Water.}} = \underbrace{2CO_2}_{\text{Carbonic acid.}} + \underbrace{C_2(2C_2H_3, H_2)N_2O_2}_{\text{Dimethyl-urea.}}$$

$$\underbrace{2C_2(C_6H_5)NO_2}_{\text{Cyanate of allyl.}} + 2HO = 2CO_2 + \underbrace{C_2(2C_6H_5, H_2)N_2O_2}_{\text{Diallyl-urea (sinapoline).}}$$

The hydrogen in urea, at least one equivalent of it, may also be replaced by negative radicals. The general method of formation of these *ureides*, so called in allusion to their amidic analogy, is the reaction of urea on the chloride of the negative radical, hydrochloric acid being eliminated. Thus are obtained:—

Acetyl-urea or aceturcide . .	$C_2(C_4H_3O_2, H_3)N_2O_2$
Butyryl-urea or butyrureide . .	$C_2(C_8H_7O_2, H_3)N_2O_2$
Valeryl-urea or valerureide . .	$C_2(C_{10}H_9O_2, H_3)N_2O_2$
Benzoyl-urea or benzureide . .	$C_2(C_{14}H_5O_2, H_3)N_2O_2$

Constitution of urea. Urea is now generally considered to be a diamine; that is, diammonia, in which two equivalents of hydrogen are replaced by the diatomic radical carbonyl (C_2O_2''):—

$$C_2H_4N_2O_2 = N_2\left\{\begin{matrix}C_2O_2''\\H_2\\H_2\end{matrix}\right.$$

Obviously, any of the compounds already described in this article could be formulated on the typical diagram $N_2\left\{\begin{matrix}C_2O_2''\\R\ R\\R\ R\end{matrix}\right.$, R being any radical; the formula of several ureas will, in fact, be found so written in the article ORGANIC BASES.

Estimation of urea. The amount of urea in a specimen of urine is often required to be known by the physiologist and pathologist. It was originally determined in the state of nitrate or oxalate, a known quantity of urine being taken and treated in the manner already indicated; results so obtained, however, have been shown to be very inaccurate. Ragsky and Heintz proposed to take advantage of the facts, that urea is decomposed into ammonia and carbonic acid when boiled with strong acids, and that ammonia may be estimated by bichloride of platinum, the weight of which would indicate the urea present in the quantity of urine acted upon; this method, however, is not universally applicable. Bunsen takes a weighed quantity of urine, mixes it with an ammoniacal solution of chloride of barium, seals it hermetically in a glass tube, and heats it to a temperature of from 250° to 460° Fahr. for several hours; carbonate of baryta is thus produced, the weight of which indicates the amount of urea originally present, inasmuch as urea is under these circumstances always split up into ammonia and carbonic acid: this process gives accurate results, but requires too much chemical skill and experience to be very generally applicable. Liebig's process for the estimation of urea (and chloride of sodium) in urine is the one now always used. It is a volumetric method, and depends upon the facts already mentioned concerning the combinations of urea with nitrate of peroxide of mercury.

From the following details it will be found that certain standard solutions have to be made; these require time and care, but, when once obtained, the actual analytical operation is one requiring a few minutes only and is very easy of execution. Solution of mercuric nitrate occasions a white precipitate in pure solutions of urea, but not in such impure solutions as urine; this is because chloride of sodium is present in the urine, and the chlorides of the metals of either the first or second groups décompose mercuric nitrate, mercuric chloride, which does not precipitate urea, being formed. But on adding mercuric nitrate to urine until the whole of the chloride of sodium is converted into nitrate of soda, further addition will cause a precipitate because nitrate instead of chloride of mercury will then come in contact with the urea. Obviously now if the strength of the mercuric nitrate solution—which may be distinguished as No. 1—be known, the amount of chloride of sodium in the urine will be at once indicated. The means by which the No. 1 solution is standardised will be given presently. It might be thought that the further addition of the same mercuric nitrate until no more precipitate falls, a point easily ascertained, would afford the means of determining the amount of urea present; but it is not so, probably because the mercuric chloride formed would keep some of the urea in solution, a definite compound of the two having, in fact, been produced. The exact amount of chlorine in the urine therefore having been thus determined, it must now be got rid of by adding to a fresh portion of urine the requisite quantity of a solution of nitrate of silver of known strength. The chloride of silver having been separated by filtration, the filtrate is treated with mercuric nitrate solution (No. 2) until the whole of the urea is precipitated, a point that is ascertained by the yellow colour produced, on putting a drop of the mixture containing the precipitate on to a drop of carbonate of soda solution placed on a white plate; the yellow colour (mercuric oxide) simply showing that mercuric nitrate is then in solution, a state of things that obviously cannot occur so long as urea exists in the liquid.

The only remaining fact to be noticed in connection with this process, before describing the method of preparation of the standard solutions, is that phosphoric acid and phosphates must be removed from the urine before commencing the analysis; this is readily accomplished by adding to any portion of the urine half its bulk of a mixture of two parts of cold saturated baryta water, and one part of cold saturated aqueous solution of nitrate of baryta, and filtering; remembering, of course, that only two-thirds of the filtrate is urine. The filtrate will probably be alkaline from excess of baryta, if so, nitric acid must be added till it is exactly neutral to test paper, and the determination of chloride of sodium and urea then proceeded with. The quantity of the filtrate most convenient for manipulation is 225 grains (=150 grains of urine) for determining the chloride of sodium; and 450 grains (=300 grains of urine) for determining the urea. The indicated number of grains of nitrate of silver solution having been added to the 450 grains just mentioned, exactly one-half of the filtered product (=150 grains of urine), is the quantity recommended to be used for estimating the urea by the No. 2 mercuric nitrate solution.

Solution of mercuric nitrate is obtained on dissolving pure mercury in nitric acid, and boiling until the solution gives no indication of mercurous nitrate on the addition of alkaline chloride. It is then evaporated to dryness over a water-bath and redissolved in seven or eight times its bulk of water. For the No. 1 solution above described, the strong liquid just mentioned is standardised by pure chloride of sodium; and for No. 2 by pure urea. Pure chloride of sodium solution is procured by digesting excess of pure rock-salt in distilled water for one or two days, the whole being occasionally well agitated: 100 water grain measures of such a solution contain, at all ordinary temperatures, 31·84 grains of chloride of sodium: 150 grain measures of this solution of salt are mixed with 45 grain measures of a solution of pure urea containing about 4 per cent. of that substance, and also with 75 grain measures of a cold saturated solution of pure sulphate of soda; the solution of mercuric nitrate is then to be added to the mixture until a distinct permanent precipitate is formed. The number of grain measures of mercuric nitrate solution added corresponds, of course, to 47·76 grains of chloride of sodium: it must then be so diluted that 100 water grain measures may correspond to one grain of chloride of sodium, the resulting liquid being mercuric nitrate solution No. 1. The No. 2 solution is prepared by adding the strong mercuric nitrate solution to 150 grain measures of distilled water containing exactly 2 per cent. of pure urea until a yellow colour is produced, with carbonate of soda in the manner already indicated; the strong solution must then be diluted until 100 water grain measures exactly correspond to one grain of urea. Finally, the nitrate of silver solution, employed for removing the chlorine of the chloride of sodium in urine after the amount of the latter has been indicated by the No. 1 solution, is prepared by dissolving 174·36 grains of fused nitrate of silver in water, and diluting till the whole amounts to 6000 grain measures; 100 water grain measures of the resulting liquid will correspond to one grain of chloride of sodium.

UREA, ESTIMATION OF. [UREA.]

UREAS. [UREA.]

URETHANE. [CARBAMIC ACID.]

URETHRA. [BLADDER, DISEASES OF THE.]

URETHYLANE. [CARBAMIC ACID.]

URIC ACID. [URIC GROUP.]

URIC GROUP, a cluster of chemical compounds, derivatives, or congeners of uric acid. Next to uric acid itself, the products of its artificial oxidation claim chief interest, inasmuch as they illustrate some of the changes which oxygen effects upon the exhausted tissues of the human frame prior to their elimination as urea. Thus uric acid plus moisture and oxygen yields urea and a body termed alloxan. Alloxan plus moisture furnishes urea and mesoxalic acid; and mesoxalic acid contains no nitrogen, the latter element having thus artificially been thrown out from uric acid as urea. It is probable that this change, or a similar one, occurs naturally in animals; for although uric acid is nearly always present in human urine, its quantity is much modified by diet. It does not occur in the urine, but does in the spleen, of the dog; and Professor Haughton, who has paid considerable attention to the physiology of this body, says that "no uric acid whatever should occur in the urine of man in perfect health, but all the nitrogen of the urine should pass off in the form of urea,—a more highly oxidated product than uric acid."

The following list includes nearly all the members of the uric group. The consideration of those of them derived from uric acid is supposed to be simplified by assuming that body to contain the radical *uril* (*uryl*) or *cyanoxalic acid* ($C_8N_2O_4=C_4O_4Cy_2$); that is, oxalic anhydride, in which two equivalents of oxygen are replaced by two of cyanogen: but uril has not been isolated, and its usefulness is very slight.

Uric (lithic) acid	$2HO, C_{10}H_2N_4O_4$
Uroxanic acid	$2HO, C_{10}H_8N_4O_{12}$
Alloxan	$C_8H_2N_2O_8$, 2 aq.
Dialuric acid	$HO, C_8H_3N_2O_7$
Uramilic acid	$C_{16}H_{10}N_5O_{15}$
Alloxantin	$C_8H_2N_2O_8+C_8H_3N_2O_7$, 5 aq.
Alliturie acid	$C_6H_3N_2O_4$
Dilituric acid	
Amalic acid (dimethyl-alloxantin)	$C_{16}(C_2H_3)_4N_4O_{14}$
Alloxanic acid	$2HO, C_8H_2N_2O_8$
Leucoturic acid	$C_6H_3N_2O_6$?
Difluan	$C_6H_4N_2O_5$?
Mycomelic acid	$HO, C_8H_3N_4O_3$, aq.
Mesoxalic acid	$2HO, C_6O_8$
Parabanic acid	$2HO, C_6N_2O_4$
Oxaluric acid	$HO, C_6H_3N_2O_7$
Uranil (murexan or dialuramide)	$H_2N, C_8H_3N_2O_6$
Thionuric acid	$2HO, C_8H_3N_3O_6, 2SO_2$
Murexid (purpurate of ammonia)	$C_{24}H_{12}N_{10}O_{16}$
Allantoin	$C_8H_6N_4O_6$
Hidantoic acid	$HO, C_8H_5N_4O_5$
Allanturic acid	$HO, C_{10}H_6N_2O_8$
Lantanuric acid	$HO, C_6H_4N_2O_6$
Xanthic (uric) oxide or urous acid	$C_{10}H_4N_4O_4$
Hypoxanthin	$C_{10}H_4N_4O_2$
Guanine	$C_{10}H_5N_5O_2$
Cystin	$C_6H_6NO_4S_2$

Uric Acid ($2HO, C_{10}H_2N_4O_4$).—This substance, sometimes called *lithic acid*, was discovered by Scheele; Vauquelin afterwards found it in the excrements of serpents, Brugnatelli in that of silkworms, and Roubiquet in cantharides.

Uric acid is secreted by carnivorous animals, birds, and by several insects. When in excess, it is deposited from human urine as a brownish-yellow powder, which is usually a compound of uric acid and ammonia. It occurs, in combination with soda or ammonia, in those gouty concretions commonly called *chalk-stones*, and it constitutes the principal portion of the calculi deposited in the human bladder. The semi-solid urine of serpents and birds is chiefly composed of urate of ammonia; and *guano*, the decomposed excrement of aquatic birds, and which is imported from some islands in the South Sea and extensively used as a manure, contains a large quantity of urate of ammonia.

This acid is conveniently obtained by dissolving the excrement of serpents—the boa constrictor, for example—in a solution of potash, and decomposing the clear solution by the addition of hydrochloric acid. It may also be obtained from the excrement of pigeons and other birds by the same process. According to Liebig, it is better to employ borax as a solvent than a caustic alkali, it dissolving less of the animal matter. On the large scale, as a source of murexia as a pigment, uric acid is obtained from guano, which is treated first with hydrochloric acid to remove carbonates and phosphates of lime, magnesia, and ammonia, then with boiling caustic soda, which dissolves the uric acid from sand, clay, gypsum, &c.; and the alkaline solution is finally treated with hydrochloric acid, which precipitates the uric acid, in a state sufficiently pure for conversion into murexia.

Uric acid occurs in small, fine, white, silky, crystalline scales; it is inodorous and insipid, heavier than water, and nearly insoluble in it when cold, and only slightly dissolved by it when hot; the solution reddens litmus-paper, but feebly. It is insoluble in alcohol or ether.

Nitric acid, even diluted, dissolves uric acid with brisk effervescence; the gases evolved consist of equal volumes of nitrogen and carbonic acid. The solution contains alloxan, alloxantin, urea, parabanic acid, ammonia, and other variable products. When the solution is evaporated to dryness, the residue is of a fine purple colour: the formation of this residue is a test of the presence of uric acid, its colour is much intensified on the addition of ammonia.

Sulphuric acid when concentrated dissolves uric acid, and forms a crystalline compound with it; it is decomposed on the addition of water; concentrated hydrochloric acid dissolves it in greater quantity than water.

Uric acid, when submitted to destructive distillation, yields the same products as urea, namely, cyamelide, cyanic acid, cyanuric acid, hydrocyanic acid, a little carbonate of ammonia, and a brown carbonaceous residue containing much nitrogen. In this decomposition the hydrated cyanic acid and ammonia combine in the neck of the retort and form urea. The cyamelide dissolves in potash, and yields cyanurate of potash.

When uric acid is heated with a little water to 392° Fahr. in a closed tube, it is converted, without any disengagement of gas, into a yellow transparent liquor, which becomes a yellow gelatinous mass when it cools; this is soluble both in cold and hot water: the alkalies evolve ammonia from it, and with the acids it produces gelatinous precipitates; with hot nitric acid it effervesces, and the solution by evaporation yields a reddish yellow mass, which ammonia renders purple.

Hydrate of potash when fused with uric acid produces carbonate of potash, cyanate of potash, and cyanide of potassium. When boiled in water with peroxide of lead, it is converted into allantoin and oxalic acid, urea being set free.

Saline combinations of Uric Acid.—Uric acid is dibasic, and forms neutral and acid *urates*. The urates of the alkaline metals and of the alkaline earths are but slightly soluble in cold water, but very soluble in boiling water; an excess of alkali increases the solubility; the urates are generally colourless, and are all decomposed by acids, even by the acetic acid; the uric acid, which is set free, is at first gelatinous, but soon assumes the form of fine brilliant laminæ.

Urate of Ammonia ($NH_4O, HO, C_{10}H_2N_2O_4$).—The acid salt is the only one known. Urinary calculi occasionally consist of this compound. [CALCULI.]

Urates of Potash.—The neutral salt ($2KO, C_{10}H_2N_2O_4$) is prepared by dissolving the excrements of serpents in a weak boiling solution of potash; the insoluble portion being separated by filtration, urate of potash is obtained as a white crystalline mass by evaporating and cooling the solution; this, after washing with cold water, is converted by drying into a brilliant powder, composed of very fine needles. This salt is very slightly soluble in cold water; the solution has an alkaline reaction. On passing carbonic acid through its solution, *acid urate of potash* ($KO, HO, C_{10}H_2N_2O_4$) is deposited.

Urates of Soda.—According to Dr. Wollaston, gouty concretions consist principally of these salts. They may be prepared in the same way as the urates of potash; the reactions are similar. Urate of soda is also formed when uric acid is boiled with borax.

Uroxanic acid ($2HO, C_{10}H_8N_4O_{10}$). When uric acid is boiled for a long time with caustic potash a small quantity of it, by assimilation of six equivalents of water, is converted into a new acid termed uroxanic. *Uroxante of potash* ($2KO, C_{10}H_8N_4O_{10} + 6$ Aq.) is very soluble in water, but may be obtained in rhombic tables; from its solution hydrochloric acid precipitates uroxanic acid in microscopic tetrahedra; boiling water decomposes it, carbonic acid being evolved.

Alloxan ($C_8H_2N_2O_8 + 2$ and 8 Aq.) This is the chief product of the action of cold nitric on uric acid. The latter is added to the former in small quantities at a time, carbonic acid and nitrogen escape, producing brisk effervescence, heat is evolved, so that it is sometimes necessary to artificially prevent undue elevation of temperature, 120° Fahr. being the maximum point to which the mixture should rise. After a time crystals begin to form in the liquid and, on repose, octohedra of alloxan separate out. They contain two equivalents of water, but from resolution in water crystallise in prisms containing eight equivalents of water.

Alloxan is colourless, of faint odour, unpleasant astringent taste, stains the skin pink, is very soluble in water, and has an acid reaction. By the action of sulphuretted hydrogen and similar reducing agents it yields *dialuric acid* ($C_8H_4N_2O_8$) and free sulphur:—

$$\underbrace{C_8H_2N_2O_8}_{\text{Alloxan.}} + 2HS = \underbrace{C_8H_4N_2O_8}_{\text{Dialuric acid.}} + S_2$$

The dialuric acid is crystalline, and forms crystallisable salts. Gregory's *uramilic acid* ($C_{16}H_{10}N_5O_{15}$) seems to be the bidialurate of ammonia.

Alloxantin ($C_{16}H_4N_4O_{14} + 6$ Aq.) is formed on adding together solutions of equivalent proportions of alloxan and dialuric acid, and would seem to be a compound of those substances. It may also be formed by the action of several reducing agents on alloxan. It occurs in small colourless rhomboidal prisms, slightly soluble in cold water, rather more so in boiling water; oxidising agents reconvert it into alloxan. Boiled with hydrochloric acid it yields white, pulverulent, *alliturie acid* ($C_6H_3N_2O_4$) and *dilituric acid*, which has not been fully examined. The dimethyl derivative of alloxantin is identical with *amalic acid.* [CAFFEINE.]

Alloxanic Acid ($C_8H_4N_2O_{10}$) may be considered as alloxan plus two equivalents of water. It is a product of the action of bases upon alloxan, and may be isolated on treating an alloxanate with a stronger acid. By evaporation it is obtained as a semi-crystalline mass, of unstable character. Its aqueous solution, by ebullition and evaporation to near dryness, splits up into *leucoturic acid* ($C_6H_3N_2O_6$?) which dissolves on rediluting with water, and a white, insoluble, slightly acid powder termed *difluan*. Some of the *alloxanates* crystallise readily.

Mycomelic Acid ($HO, C_8H_3N_4O_3$, Aq.), or *alloxanamide*, is formed when a solution of alloxan in ammonia is boiled and cooled slowly.

$$\underbrace{C_8H_2N_2O_8}_{\text{Alloxan.}} + 2NH_3 = \underbrace{HO, C_8H_3N_4O_3}_{\text{Myoomelic acid.}} + 4HO$$

Mesoxalic Acid ($2HO, C_6O_8$). Where solutions of alloxanates are boiled for some time, they break up into urea and mesoxalic acid:—

$$\underbrace{2BaO, C_8H_2N_2O_8}_{\text{Alloxanate of baryta.}} + 2HO = \underbrace{2BaO, C_6O_8}_{\text{Mesoxalate of baryta.}} + \underbrace{C_2H_4N_2O_2}_{\text{Urea.}}$$

Mesoxalic acid may be isolated from the baryta salt by sulphuric acid or from the lead salt by sulphuretted hydrogen. It is very soluble in water, but may be obtained in crystals. The silver salt is decomposed when heated, brisk effervescence of carbonic acid and carbonic oxide occurring.

Parabanic Acid ($C_6H_2N_2O_6$) may be obtained in flat colourless prisms on evaporating the nitric acid with mother liquor of alloxan. It is permanent itself, but forms unstable compounds with bases. The parabanate of ammonia, for example, decomposes during evaporation the ammonia salt of *oxaluric acid* ($NH_4O, C_6H_3N_2O_7$) being formed. The latter occurs in brilliant crystals, and is interesting from the fact that dumb-bell crystals of oxaluric acid—at first mistaken for oxalate of lime—are sometimes met with in urinary deposits.

Phenyl-oxaluramide or *oxaluranilide*, ($C_{18}H_9N_3O_6$) is a white crystalline powder.

Thionuric Acid ($2HO, C_8H_3N_3O_6, 2SO_2$). Solutions of alloxan, sulphite of ammonia, and ammonia, combine together when boiled, thionurate of ammonia crystallising out on cooling in brilliant leaflets. The lead salt decomposed by sulphide of hydrogen furnishes an acicular mass of thionuric acid.

Uramil ($NH_2, C_8H_3N_2O_6$) *murexan* or *dialuramide.* When a hot saturated solution of thionurate of ammonia is treated with hydrochloric acid in excess, the mixture is converted into a semifluid mass. The uramil thus obtained is in the form of plumose acicular crystals, which are permanent in the air, and become of a pink colour when heated; they are insoluble in cold and but slightly soluble in boiling water. The alkalies dissolve uramil, and acids precipitate it from them unchanged. The solutions in ammonia and potash become of a purple colour by exposure to the air, and deposit green acicular crystals of a brilliant metallic lustre. If the potash solution be boiled, ammonia is evolved and *uramilic acid* is formed; dilute acids produce similar decomposition. It is soluble in concentrated sulphuric acid, and is precipitated from it by water; by concentrated nitric acid it is resolved into alloxan, with the evolution of hyponitrous acid, and the formation of nitrate of ammonia.

Murexid ($C_{24}H_{12}N_{10}O_{16}$?), *purpurate of ammonia* of Dr. Prout. This substance may be obtained by several processes. The least operose is probably that of dissolving uric acid in dilute nitric acid, evaporating the solution till it assumes a reddish colour; after the liquor has cooled to 158° Fahr., add excess of ammonia; then dilute it with half its volume of boiling water, and allow it to cool. Care must be taken not to employ too much or too little nitric acid. Whilst ammonia continues to give a red precipitate, when added to small portions, the nitric acid is insufficient. If, on the contrary, ammonia produces a glairy yellow precipitate, murexide cannot be obtained without passing a current of hydrosulphuric acid into the liquor.

Murexide crystallises in short four-sided prisms, which exhibit a green metallic reflection. They are garnet-red by transmitted light. It is very little soluble in cold water, and gives it a magnificent purplish red colour. It dissolves readily in water at 158°, and crystallises from the solution unaltered. It is insoluble in alcohol and in ether. It is insoluble also in solution of carbonate of ammonia, but dissolves in a solution of potash, producing a superb indigo-blue colour, which disappears by heat, with the evolution of ammonia.

Purpurate of Potash.—According to Fritzche, this is best obtained by decomposing a boiling solution of purpurate of ammonia by means of excess of nitrate of potash. This purpurate consists of very small reddish-brown crystals; it may however be obtained in large crystals, which have the colour and lustre of the ammoniacal salt. It is difficultly soluble in water, and much less so in saline solutions, and hence the advantage of using excess of nitre in preparing it. It appears to be a neutral salt.

Purpurate of Soda is of a dark brick-red colour, and may be obtained in crystals; it is much less soluble in water than the potash salt, requiring 3000 times its weight for solution, or even more at 60°. The *purpurates of lime, baryta,* and *strontia* are still less soluble than those above described; they are of a deep greenish colour, but when dissolved in water they impart a purple colour to it. There are two salts of lime; one of which is a bulky red crystalline powder, and the other, which is greenish-black, appears to be a subsalt. The *purpurate of magnesia* is very soluble.

When purpurate of ammonia is added to a solution of metallic salts, the effects produced are as follows:—Cobalt, a granular reddish precipitate; zinc, a fine yellow; tin, a scarlet precipitate; mercury, protosalts, a purple precipitate; persalts, a pale rose precipitate; silver, a deep purple one; the salts of lead, iron, nickel, and copper, the chlorides of gold and platina, alter their colour by the addition of purpurate of ammonia, but are not precipitated by it. The pink sediment which generally appears in the urine of those labouring under febrile affections, appears to owe its colour to the purpurate of ammonia.

Allantoin ($C_8H_6N_4O_6$); *allantoic* or *anniotic acid.* A product of the oxidation of uric acid by peroxide of lead in a boiling solution; the hot filtered solution deposits colourless brilliant crystals of allantoin. Allantoin also occurs in the urine of the fœtal calf, and in the allantoic fluid of the cow. It is a neutral body, tasteless, inodorous, tolerably soluble in boiling water, but only slightly so in cold water. Left in contact with strong caustic potash for a few days it appears to assimilate two equivalents of water and become *hydantoic acid* ($C_8H_5N_4O_8$). Solution of allantoin, heated in a closed tube to 280° Fahr., gives white deliquescent *allanturic acid* ($HO,C_{10}H_5N_4O_5$) insoluble in alcohol. *Lantanuric acid*, a product of the action of ferrocyanide of potassium upon uric acid, is probably identical with allanturic acid.

Xanthic, or *uric oxide* ($C_{10}H_4N_4O_4$) or *urous acid,* forms the chief constituent of a rare form of urinary calculus. It is also contained in the intestinal concretions of animals or BEZOARS. It is soluble in alkalies, but is reprecipitated as a white powder by acids, and is insoluble in water, alcohol, or ether.

HYPOXANTHIN, GUANINE, and CYSTIN are treated of in separate articles.

URIC OXIDE. [URIC GROUP.]

URIC SERIES. [URIC GROUP.]

URIL. [URIC GROUP.]

URINARY CALCULI. [CALCULI.]

URINE, PATHOLOGY OF, AND MORBID STATES OF. The normal constituents of urine are treated of in the article URINE, in the NATURAL HISTORY DIVISION of this Cyclopædia. We shall here speak of the urine in states of disease, and more particularly of its abnormal constituents. These latter may be divided, first, into those substances which are dissolved in the urine; and, second, those substances which are thrown down as sediments.

1. Substances which are dissolved in the urine, or precipitated only under special conditions.

Hæmatin, or blood-pigment, appears in the urine in two states, either in the blood-cells or independent of them. When the latter occurs, the blood is of a more or less brown or black colour. Such a condition does not indicate the rupture of blood-vessels, but a state of the blood produced by such diseases as typhus fever, yellow fever, scarlatina maligna, scurvy, pyæmia, and other diseases in which the blood-cells are, as it were, broken up.

Albumen is frequently present in the blood, but is not characterised by any particular physical appearance: it often is of a natural colour, sometimes a little paler, at other times it is obviously tinged with blood. For the most part albuminous urine is transparent at the instant it is voided, but on cooling it becomes turbid: its odour is ordinarily less urinous than the urine of health. The tests for detecting albumen are various. Nitric acid is one of the best; for if a few drops be added to the urine containing albumen, a precipitate is formed, which we cannot re-dissolve by an excess of the acid, but which is readily dissolved by the addition of a sufficient quantity of alkali. Heat, from its property of quickly coagulating albumen, is an excellent test for recognising this principle, as it has the advantage of not coagulating the other elements of urine. Albuminous urine, on being exposed to a temperature of about 150°, becomes opaque, and deposits the principle in a coagulated state. The precipitate varies considerably in appearance in different instances, being sometimes firm and similar to that formed by the serum of the blood, from which it may then be supposed to be derived; while at other times it is delicate, fragile, and somewhat resembling curd, when it may be supposed to be of chylous origin.

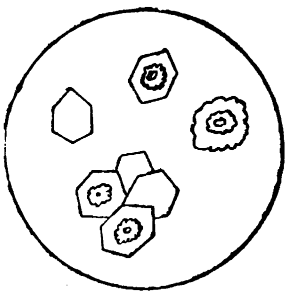
Albumen is generally indicative of disease of the kidneys. [KIDNEYS, DISEASES OF.] This form of disease may come on in many diseases, such as intermittent fever, typhoid fever, measles, small pox, inflammation of the lungs, phthisis, rheumatism, chlorosis, and disease of the heart. It has also been observed in temporary derangement of the digestive organs, and even in health after eating albuminous food, such as eggs. Dr. Parkes found, on examining indiscriminately all cases admitted under his care, that about 25 per cent. had albumen in the urine, and that of these 12 per cent. were temporary, and 13 per cent. were permanent.

In some cases the albumen in the urine is of a modified character, so that although not precipitated by heat or nitric acid alone, nitric acid will cause a precipitate when it is heated.

Xanthic (*Uric*) *Oxide* was first described by Dr. Marcet, and subsequently by Professor Stromeyer. It is said by Liebig to differ from uric acid by containing one proportion less of oxygen. The characters of urine containing this substance are not known, as the urine of the persons from whom the xanthic oxide calculi hitherto met with were taken was not analysed.

Cystic Oxide does not exist in healthy urine, but is occasionally found in certain states of disease. It contains a considerable proportion of sulphur, no less than two atoms being present in each equivalent of the oxide. This substance, when present in the urine, is always in a white crystallised state, never being found amorphous. When urine which contains a deposit of this kind is mixed with hydrochloric acid it is not rendered clear; on the application of heat, however, the cystine slowly dissolves.

Dr. Bird says that when a deposit suspected to contain cystine is examined, it should be washed with boiling water to remove the urates and any crystals of common salts which might be present, and then placed in a drop of water on a slip of glass under the microscope. Crystals of cystic oxide will then be readily distinguished, by their presenting one or other of two forms under which it occurs. In the first of these it appears under the form of tolerably regular six-sided tables, sometimes transparent throughout, but more generally opaque in the centre. In the second it occurs as roundish tables, opaque in the centre, and often quite so, somewhat crenate at the edges.



Cystic Oxide Crystals.

Cystic oxide may be distinguished by its solubility in alkalines and most acids, and by the characteristic odour it yields when burnt. It is however very little soluble in acetic acid; hence when cystic oxide exists in the urine, it may be readily precipitated from that fluid by vinegar.

Leucin has also been found in the urine. This substance exists normally in the spleen, liver, pancreas, and thymus gland. It has been found present in the urine in disease of the liver.

Tyrosin, *Hypoxanthin*, and tannin have been also found in the urine.

Sugar does not exist in healthy urine, but in certain states of disease it is found in large quantities. Sugar of diabetic urine differs in appearance from common sugar, and approaches in its properties to the sugar of grapes, with which it is identical in composition. Urine containing sugar is generally pale-coloured, of specific gravity above 1·030, and its natural ingredients are often relatively much diminished in quantity. This substance is present in the disease called diabetes. [DIABETES.]

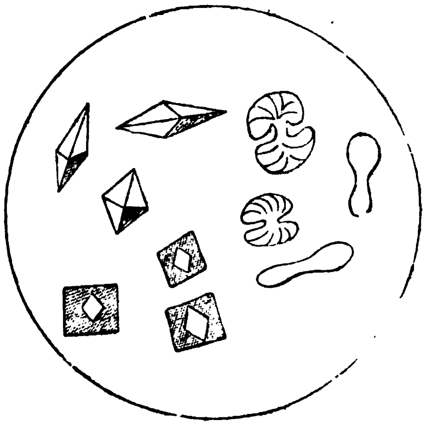
Sugar is found temporarily present in the urine, and is supposed to be produced by a casual absence of oxidation. Thus it has been observed in the urine after temporary injuries of the head. It has also been said to occur in all cases in which respiration is impeded, emphysema, hooping-cough, epilepsy, hysterics, &c.

Colouring matters of various kinds have been found in the blood. Prout first observed indigo in the urine. Hassall examined this subject, and found indigo present in several kinds of urine. Heller has also discovered a blue colouring matter in urine, which he calls moxanthin. This substance is closely related to indigo, and probably both are produced by the same series of changes. A green pigment and a pink pigment, called euroerythrin, have also been found in urine in various forms of disease. Bile pigments are not unfrequently present in the urine of even healthy persons, and are constantly present in those affected with jaundice.

Various acids besides the normal acids have been found in urine. Such are the bile acids, taurocholic and glycocholic, acetic, lactic, butyric, and nitric acids. Sulphuretted hydrogen is also occasionally detected in the urine when first passed.

Of the abnormal sediments in the urine, the most frequent and interesting is the salt of lime with :—

Oxalic Acid—Oxalate of Lime. Oxalic acid is never found in healthy urine, although, according to the important investigations of Dr. Golding Bird, deposits of oxalate of lime are of common occurrence. Where the acid does not result from the peculiar character of the ingesta containing it, as rhubarb or sorrel, the occasion of this morbid deposit is the formation of oxalic acid in the living body, possibly from some undue oxidation of carbon within the kidney. So strong is the affinity between lime and oxalic acid, and so great the insolubility of the resulting compound, that the addition of a very minute quantity of oxalic acid occasions in the urine a precipitate of oxalate of lime, because the oxalate, unlike the phosphate of this earth, is not at all soluble in the natural acid of the secreted fluid. Dr. G. Bird says, that when deposits of oxalate of lime exist, the urine is acid; in tint varying from a pale straw colour to deep amber, sometimes nearly limpid, much more generally containing a copious deposit of urate of ammonia of a very pale colour, rarely being tinged with pink; and frequently mixed with uric acid and numerous fragments of epithelium; the specific gravity generally exceeds the average density of healthy urine, but sometimes is below it, varying from 1·016 to 1·029. An excess of urea is frequently present, so that when the urine is above the density of 1·020, it crystallises very quickly after the addition of an equal bulk of nitric acid. When the urine contains no urate of ammonia the deposit of oxalate of lime, on account of its transparency, is generally nearly imperceptible; but on decanting the superabundant fluid, after a few hours' repose, and placing a few drops of the lowermost layers in a capsule, a white crystalline sediment is very readily distinguishable, and this, when examined under the microscope, presents a very beautiful appearance. The crystals are of three forms, octahedra, hour-glass or dumb-bell bodies, and small flattened disc-like bodies sometimes round but more frequently elongated, which may be the beginning of the dumb-bell crystals. The octahedral crystals are the most common. Bird and others have attributed a variety of symptoms to the presence of oxalic acid in the system, but Lehmann and Scherer have denied that any connection whatever can be traced between the symptoms described and the appearance of oxalate of lime in the urine. Such a view is also supported by those writers who maintain that the oxalic acid is not formed in the blood at all, but is the result of changes in other constituents of the urine after it has passed from the bladder.



Oxalate of Lime Crystals.

Carbonic Acid; Carbonate of Lime.—Carbonic acid was long ago supposed to exist in urine, although its existence in this fluid is doubted by Berzelius. Dr. Prout says that he has frequently met with this acid in urine, and is most frequently derived from the decomposition of urea, which with water is readily converted into carbonate of ammonia. Carbonate of lime is occasionally found in the urine, and is probably formed by the reaction of carbonate of ammonia on the phosphatic salts: the urine in these cases is alkaline. Carbonate of lime dissolves with effervescence in dilute acid.

Uric Acid frequently exists in larger quantities than natural, and is then precipitated in the urine, either with or without bases. When combined with bases it forms what is called the "calculous sediment" of urine. The exact composition of the sediments of uric acid with bases has been the cause of much dispute. At one time all uric acid deposits were considered as combinations of the acid with ammonia. Subsequent analysis has shown that urate of soda is a very common sediment. These deposits occur either directly after the urine has cooled down to the temperature of the external atmosphere, or some hours after. In the latter case the production of some other acid by decomposition is the cause of the precipitate. These deposits may not alone occur from increase of uric acid in the urine, but also from a decrease of water in the urine and a relative increase of uric acid. The formation of other acids may also cause this. Sometimes the uric acid is deposited without any base, and then assumes its characteristic forms. This may arise from excess of uric acid, but it may also arise from the formation of such acids as the sulphuric, phosphoric, hippuric, lactic, oxalic, or other acids.

Phosphoric acid forms sediments of the ammoniaco-magnesian phosphate, the phosphate of lime, and the phosphate of magnesia. The cause of the deposit of the ammoniaco-magnesian phosphate is the decomposition of the urea. The carbonate of ammonia thus produced lessens the acidity of the urine, and the ammonia partly combines with the phosphate of magnesia. As soon as the acidity declines the ammoniaco-magnesian phosphate is deposited with phosphate of lime.

If the urine become alkaline from potash or soda, and not from ammonia, then the phosphates of lime and magnesia are thrown down. This occurs after eating much vegetable food, or after the carbonates or the mixed alkalies have been used for a length of time as medicines. This group of deposits often become the source of stone in the bladder. [CALCULUS.]

The next group of abnormal deposits in the urine are those which have never been dissolved in the urine, and which fall when the urine is allowed to stand. These are mostly organic, and are detected chiefly by the aid of the microscope.

Blood is often poured out in abundance from the mucous membrane lining the urinary passages, and is generally diffused through the urine, or is passed entire. In other cases small quantities of blood are passed mixed with pus or mucus, or alone, after the urine has been voided. When large quantities of blood are passed, especially without pain, it is probably a simple exudation from some part of the mucous surface of the urinary organs; on the other hand, when the blood is mixed with pus or mucus, and passed with pain, it denotes ulceration of the kidney or bladder, and may be combined with the existence of a foreign body in the bladder. Dr. Willis, and other writers, quote several authorities to show that hæmaturia is endemic in some countries. M. Chapotain, for instance, informs us that in the Isle of France children from their infancy are liable to hæmaturia without suffering any pain from it, or its appearing to prejudice their general health. M. Salesse, a native of the Isle of France, and now a practitioner of medicine there, states that three-fourths of the children are affected with hæmaturia at one time or another. In these cases the bloody urine is generally observed to alternate with that which is chylous or oleo-albuminous. During the invasion of Upper Egypt by the French, many of the men suffered from an epidemic hæmaturia.

When blood corpuscles are present in the urine, of course albumen is also there. It is sometimes a question whether the albumen is greater in amount than can be accounted for by the blood or not.

Pus is often found in great abundance in the urine. Upon standing, the pus subsides to the bottom of the vessel, in a state more or less pulverulent, and the fluid resumes its transparent character. If pus be present as well as mucus, the former is found lying on the latter, and presents a much yellower tint; it is also quite opaque, whereas mucus is more or less transparent. A ready test for determining whether the deposit from the urine be of a purulent nature, is to add liquor potassæ to the sediment collected in a phial or test tube. If it be purulent, it will, on agitation, form with the alkali a transparent viscid compound.

Fat may be either dissolved in the form of a soap, or free in the urine. It is more frequently free. The urine has a turbid emulsion-like appearance. What is called chylous urine depends on the presence of fat globules. This state of the urine sometimes comes on from fatty food, and at other times from some defect in the assimilative functions. It is not at all a dangerous symptom. The administration of gallic acid is said to arrest its development.

Epithelial cells are very frequently present in abnormal numbers in urine. In all urine, after standing, a slight cloud will be seen forming, which, when examined by the microscope, is found to consist of ill-defined granular cells from the mucous membrane of the urinary passages. In many diseases this becomes increased. The shape of these cells will indicate their source. The epithelial cells of the urethra, bladder, and kidney are of different forms. The cells of the urethra are flattened, those of the bladder ovate, whilst those of the renal epithelium are caudate.

Cancer cells are also found when cancerous disease of the kidneys or bladder is present. It is very difficult to distinguish between the caudate cells of cancer and the cells of the renal epithelium. The latter are not often in such abundance as the former, but general symptoms must assist in the diagnosis.

Renal casts are frequent in the urine in disease. They vary in breadth from the $\frac{1}{500}$th to the $\frac{1}{1000}$th of an inch, and are from the $\frac{1}{50}$th to the $\frac{1}{500}$th of an inch in length. They vary, however, in size and transparency, according to the materials of which they are composed. It is, however, impossible to diagnose the nature of the disease of the kidneys by the composition of the renal cast. Large bodies are often found, called cylinders, which are not found in the kidneys, but in the bladder, prostate, or ureter. The casts have been thus named according to their composition by Dr. George Johnson: epithelial casts, large and small waxy casts, granular casts, oily casts, bloody casts, purulent casts.

Other bodies are less frequently found in the urine, as fibrine, starch, spermatozoa, hydatids, hair, and entozoa, the sources of which are indicated by their nature.

Urine sometimes, after standing, presents the mycelium of lower fungi as the *Penicilium glaucum*, cells of the feculent fungus, and vibriones and monads. These and similar growths are evidently introduced from without.

The following tables, from Dr. Golding Bird's work on urinary deposits, give the characters of the various kinds of deposits found in the urine.

Table for Discovering the Nature of Urinary Deposits by Chemical Reagents.

	It consists of
If the deposit be white, and soluble by heat . . .	Urates.
" " insoluble by heat, but soluble in ammonia	Cystine.
" " insoluble by heat and ammonia, but soluble in acetic acid .	Earthy phosphates.
" " soluble in ammonia and acetic acid	Oxalate, or oxalurate of lime.
" be coloured, and visibly crystalline . .	Uric acid.
" " amorphous, but pale and readily soluble by heat .	Urates.
, be deeply coloured, amorphous, and slowly soluble by heat	Urates stained by purpurine.

Table for the Microscopic Examination of Urinary Deposits.

	It consists of
If the deposit be amorphous, and disappear on the addition of liquor potassæ	Urates.
If the deposit be visibly crystalline, and the crystals octohedral	Oxalate of lime.
If the deposit be visibly crystalline, and the crystals hexagonal tables, soluble in ammonia	Cystine.
If the deposit be visibly crystalline, and the crystals radiated or foliaceous, not soluble in ammonia, but soluble in acetic acid with effervescence	Carbonate of lime.
If the deposit be visibly crystalline, and the crystals radiated or foliaceous, not soluble in ammonia, but soluble in acetic acid, without effervescence	Bibasic triple phosphate.
If the deposit be visibly crystalline, and the crystals be dumbbells, not soluble in ammonia, but soluble in acetic acid with effervescence	Carbonate of lime.
If the deposit be visibly crystalline, and the crystals be dumbbells, soluble by heat, but not in ammonia nor acetic acid	Urate of soda.
If the deposit be visibly crystalline, and the crystals be dumbbells, insoluble by heat, ammonia, and acetic acid . .	Oxalurate of lime.
If the deposit be visibly crystalline, and the crystals be dumbbells with fringed edges, insoluble in alcohol and acetic acid, but soluble in liquor potassæ	Uric acid.
If the deposit be visibly crystalline, and the crystals lozenge-shaped or compound, insoluble in acetic acid and ammonia	Uric acid.
If the deposit be visibly crystalline, and the crystals spherical, with or without spicules, soluble by heat . . .	Urate of soda.

As a summary of the courses and treatment of diseases indicated by a disordered state of the urine, we give the following table, drawn up by Dr. Marshall Hall, premising that considerable advance has been made in our knowledge of urinary deposits since the table was drawn up.

CAUSES.				TREATMENT.
1. Errors in diet. 2. Fatigue. 3. Dyspepsia. 4. Arthritis. 5. Dentition.	I. The Lithic.	I. Diathesis.	Urine Acid, from the Superlithate of Ammonia.	1. Wholesome Diet. 2. Mild Aperients, especially Rochelle Salt. 3. Mild Mercurials. 4. The Alkalies. 5. Magnesia. 6. The Gum Lancet.
		II. Amorphous Deposits.	I. Lithate of Ammonia, frequently mixed with the II. Lithates of Soda and Lime.	
		III. Crystals or Gravel.	Lithic Acid, nearly pure.	
		IV. Concretions or Calculi.*	I. The Lithic Acid. II. The Lithate of Ammonia.	
	tend to			
	An intermediate station is to be allotted to the Oxalate of Lime—	I. Diathesis.	Urine nearly natural.	1. Antiphlogistics. 2. Mild Aperients, *not* the Rochelle Salts. 3. Mild, wholesome Diet. 4. The muriatic Acid.
		II. Amorphous Deposit.		
		III. Crystals or Gravel.		
		IV. Calculus.	The Mulberry, or Hempseed.	
	pass into			
1. Irritability } of the 2. Debility } System. 3. Sickly Childhood. 4. 'Breaking up' of the System. 5. Injuries of the Spine.	II. The Phosphatic—	I. Diathesis.	Urine Alkaline and abounding in the Phosphates.	1. Strict Regimen. 2. Mild Aperients—as Rhubarb. 3. Opium; Hyoscyamus, &c. 4. The Uva Ursi; the Alchemilla arvensis, &c. 5. Rhenish or French Wines, Cider, Perry, Lemonade, &c.
		II. Amorphous Deposits.	I. Triple Phosphate (of Magnesia and Ammonia), mixed with II. Phosphate of Lime.	
		III. Crystals or Gravel.	Triple Phosphate.	
		IV. Concretions or Calculi.*	I. The *Triple* Phosphate. II. The *Mixed* 1. Triple Phosphate with 2. Phosphate of Lime; or the Fusible Calculus.	*Avoiding.* 1. Alkalis. 2. Salts, with a vegetable Acid, as Rochelle Salt. 3. Mercury.

* To these must be added— I. The *Alternating;* generally consisting of A Lithic acid, or Mulberry *Nucleus;* An *External Crust* or the *Mixed* Phosphates. II. The *Mixed;* generally consisting of The Lithate of Ammonia; The Phosphates.

A special place is to be allotted to The Prostatic Calculi. These consist of Phosphate of Lime alone.

Lastly—The Cystic Oxide; the Xanthic oxide; the Carbonate of Lime; the Fibrine Calculi, are all extremely rare.

Principles *dissolved* in the Urine.	Urea in excess.	Diabetes insipidus;	Urine of high Specific Gravity; as 1·020.	Blood-letting.
	Sugar.	Diabetes.	Urine profuse; sp. gr. *very* high; as 1·050. Saccharine.	Mild Animal Diet. Opium. Dover's Powder.
	Albumen.	Frequently Disease of the Kidney.	Urine coagulates by heat.	Warm Baths. Carbonate of Iron.

Principles *mixed* with the Urine.	Mucus.	Scanty when from the Kidney Profuse when from the Bladder.
	Pus. Blood.	From Calculus, or Disease, of the Kidney or Bladder.

Those who wish to master the subject of urinary pathology should study the work of Dr. Edmund Parks, 'On the Composition of the Urine in Health and Disease,' 1860. It is one of the most masterly works hitherto published on the urine. Dr. Golding Bird's work 'On Urinary Deposits;' Dr. Beale's 'Treatise on the Microscope in Medicine,' and his 'Illustrations of Urine, and Urinary Deposits,' should also be consulted. Dr. Beale's 'Tables for the Practical, Chemical, and Microscopical Examination of Urine, Urinary Deposits, and Calculi,' will be found of great service.

URINO'METER, an instrument for ascertaining the weight of urine. It is constructed on the principle of a common hydrometer, and consists of a glass tube, which at its lower extremity has two bulbs, the lower one very small, containing a heavy substance, such as mercury, and the other immediately above it much larger, and filled with air. The tubular portion contains a scale denoting with certain figures the specific gravity, the use of which will be illustrated by the following example:—Suppose the water's edge cut the scale at figure 25, then add that number to 1000, and the specific gravity will be 1·025.

URN. [Vases.]

UROERYTHRIN. A red pigment in urine.

UROGLAUCIN. [Uroxanthin.]

UROUS ACID. [Uric Group.]

UROXANIC ACID. [Uric Group.]

UROXANTHIN. A yellow colouring matter in urine, which by oxidation is said to be converted into ruby-red, *Urrhoidin*, and blue *Uroglaucin.*

URRHOIDIN. [Uroxanthin.]

URSA MAJOR and **URSA MINOR** (the Greater and Lesser Bear), two of the most remarkable constellations of the northern hemisphere: the latter as containing the pole star, or the visible star which is nearest to the northern pole of the heavens; the former from its well known seven stars, by two of which the pole star is always readily found. These seven stars, which are α, β, γ, δ, ϵ, ζ, and η of the constellation Ursa Major, are disposed in the form of a quadrangle joined by one of its corners to a triangle, and with this description it would be difficult to avoid finding them out. A line drawn from β to α, the two pointers, as they are called, passes through the Pole star when continued: these two pointers being the stars of the quadrangle which are farthest from the triangle. This Pole star (α Ursæ Minoris) is the principal star in Ursa Minor, which has seven stars placed together in a manner very much resembling Ursa Major, the Pole star being the corner of the triangle which is farthest from the quadrangle.

The common people of most countries call the seven stars of the Great Bear by the name of "the waggon," sometimes by that of "the plough." Aratus says that both the bears were called waggons by the Greeks; and 'Charles's Wain' is familiar to all our readers. The later stories of Grecian mythology are hardly worth recording: the nymph Calisto was transformed by Diana into the Great Bear for an amour with Jupiter; while the Lesser Bear is Cynosura [CYNOSURE], one of the nymphs who nursed Jupiter.

The following are the principal stars in these constellations:—

URSA MAJOR.

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
ι	9	3048	4
h	23	3221	4
θ	25	3242	3½
υ	29	3346	4
λ	33	3305	3½
μ	34	3533	3
β	48	3767	2
α	50	3777	1½
ψ	52	3812	3½
ξ	53	3851	4
ν	54	3852	4
χ	63	3981	4
γ	64	4017	2
δ	69	4123	2½
ε	77	4335	3
ζ	79	4532	3
η	85	4607	3

URSA MINOR.

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
α	1	360	3
A	5	4822	4
β	7	4936	3
γ	13	5094	3
ζ	16	5285	4
ε	22	5780	4
δ	23	6281	3

URSULINES, an order of nuns in the Roman Catholic church, founded about the year 1537, by Angela Merici, commonly called Angela of Brescia, who was born in 1511, at Desenzano, on the Lago di Garda, and died at Brescia, March 21, 1540. The institution was formally approved of and confirmed by Pope Paul III., in 1544, and it was upon this occasion that the name of Ursulines was given to the order, after the famous British Saint Ursula. The order of the Ursulines was designed mainly for the succour of poverty and sickness, and for the education of the young; and wherever it was established the nuns principally devoted themselves to these services, in rendering which they mixed freely with the world, much in the same manner as the members of the various orders of charity have always been accustomed to do. At first indeed they neither bound themselves by the usual irrevocable vows, nor even lived together in communities; and there appear to have been always some members of the order who continued to reside with their families or by themselves at their own houses. In course of time, however, the Ursulines, like the other religious orders, came for the most part to be distributed in monasteries, especially in France, where they chiefly flourished.

URYLE. [URIL.]

USANCE. [BILL OF EXCHANGE.]

USE. A use at common law was a beneficial interest in land, distinct from the legal property therein. The origin of uses is derived by Gilbert ('Law of Uses,' 3) from a title under the civil law, which allows of an usufructuary interest, distinct from the substance of the thing itself, and which was called in that law the *fidei commissio*. He says it was introduced by the clergy, who were masters of the civil law, and who, "when they were prohibited from taking anything in mortmain, after several evasions by purchasing lands of their own tenants, suffering recoveries, purchasing lands round the church, and making them churchyards by bull from the pope, at last invented this way of conveying lands to others to their own use; and this being properly matter of equity, it met with a very favourable construction from the judges of the chancery court, who were in those days commonly clergymen. Thus this way of settlement began; but it more generally prevailed among all ranks and conditions of men by reason of the civil commotions between the houses of York and Lancaster, to secrete their possessions, and to preserve them to their issue, notwithstanding attainders; and hence began the limitation of uses with power of revocation." But whatever may have been the origin of uses, it is certain that the desire of effecting frequent and secret transfers of property without resorting to the simple and public modes of conveyance of the common law, as well as the natural desire to dispose of property by devise, which the common law did not allow, led to an early adoption of the system.

The system of uses having been found to produce many inconveniences, notwithstanding the statutes which had been passed from time to time to modify them, it was thought a remedy would be found by joining the possession to the use, or, as it is usually termed, transferring uses into possession. With this view the statute of 27 Hen. VIII., c. 10, commonly called the Statute of Uses, was passed, which enacted, that where any person or persons stood or were seised, or at anytime thereafter should happen to be seised of any honours or other hereditaments to the use, confidence, or trust, of any other person or persons, or of any body politic, by any manner of means whatsoever it should be, that in every such case all such person and persons, and bodies politic, that had or thereafter should have any such use, confidence, or trust in fee simple, fee tail for term of life, or for years or otherwise, or any use, confidence, or trust in remainder or reverter, should from thenceforth stand and be seised, deemed, and adjudged in lawful seisin, estate, and possession of, and in the same honours and hereditaments with their appurtenances, to all intents, constructions, and purposes in the law, and in all such like estates as they had or should have in use, trust, or confidence of or in the same; and that the estate, title, right, and possession that was in such person or persons that were or thereafter should be seised of any lands, tenements, or hereditaments, to the use, confidence, or trust of any such person or persons, or of any body politic, should be from thenceforth clearly deemed and adjudged to be in him or them that had or should have such use, confidence, or trust, after such quality, manner, form, and condition as they had before in or to the use, confidence, or trust, that was in them.

It has been questioned whether or not the legislature intended by this act to put an end to the system of uses; nevertheless it was soon settled that it had not that effect, but that uses might still as formerly be raised, upon which the statute would instantly operate. However, some modifications of the system were introduced. Before the statute a mere agreement for sale, without words of inheritance, was sufficient to pass the equitable fee to the vendee; but by the 27 Hen. VIII., c. 16, it was enacted that no contract should transfer the legal estate in the fee, unless it were made by deed enrolled. And it was resolved by the judges that words of inheritance were necessary to pass the fee at law. Indeed no contract importing a future conveyance, even though made by deed enrolled, and containing words of inheritance, would now be held to transfer the legal estate under the Statute of Uses, though it would entitle the vendee in equity to call for a regular conveyance. A further modification of the system of uses was introduced by the seventh section of the Statute of Frauds (29 Car. II., c. 3), which required that all declarations of trusts or confidences of lands, tenements, or hereditaments (which might formerly have been created by parol), should be manifested and proved by writing, signed by the party by whom it is declared.

In order to raise a use which the statute will turn into a possession, it is necessary that there should be, 1st, one person seised to the use of another, *in esse*; 2nd, a use *in esse*, limited in possession, reversion, or remainder. The use may be either *express*, as where lands are conveyed to A and his heirs, in trust for B and his heirs, or in confidence that he and they shall take the profits, or where a vendee, for a valuable consideration, conveys by bargain and sale enrolled, in both which cases the legal estate vests in the grantee or bargainee by the statute; or it may be *implied*, as where a feoffment is made without consideration or declaration of the use, in which case the use results, and the estate returns to the grantor.

It was settled by the courts of law that the statute could not operate except upon an estate of freehold, and that therefore copyhold and leasehold estates are not affected by it. A term of years may of course be created out of a freehold estate by way of use, but when once subsisting cannot be conveyed to uses. If, therefore, a term were assigned to A to the use of B, the legal estate would remain in A, who however would be considered in equity as a trustee for B.

By the operation of the Statute of Uses, a man may, through the medium of a feoffee or releasee, make a conveyance to his wife, which he could not do at common law (Litt., s. 168; Co. Litt., 112 a.). In like manner a married woman, having a power, namely, a right to limit a use, may appoint to her husband.

At common law a man could not limit a remainder to himself, nor could he limit it to his heirs so as to make them take as purchasers, without departing with the whole fee simple out of his person (Dyer, 156 a, fol. 24; Co. Litt., 22 b.), but he may do so by means of a conveyance operating under the statute.

It is a rule of the common law that joint tenants cannot take at different periods. (1 Co., 100, b. 2.) Again, by its rules, a fee could not be limited upon a fee; a freehold could not be made to commence *in futuro*, and an estate could not be made to cease by matter *ex post facto*, so as to let in another limitation before the expiration of the former. [REMAINDER.] But limitations of the above kinds may be made to take effect under the Statute of Uses. Such limitations are called *shifting or secondary* and *springing uses*; and *future or contingent uses*.

Shifting or Secondary Uses are properly such as take effect in derogation of some other estate, and are either limited expressly by the deed, or are authorised to be created by some person named in the deed: as if an estate were limited to the use of A and his heirs, with a proviso that if B pay 10*l.* the estate shall go to B and his heirs. Shifting uses seem to have existed before the statute, when, as the legal estate remained in the feoffees, the rule of the common law, which did not allow the fee to change from one to another except upon breach of a condition annexed to the estate at its creation, was not violated. They are now of constant occurrence in settlements of property. [Settlement.] The rules against perpetuities in settlements of property are applicable to shifting uses, which must be limited to take effect within the same period, namely, that of a life or lives in being, and twenty-one years afterwards, unless where they are to take effect after an estate tail, in which case, as the tenant in tail may defeat the use by barring the estate tail, such a limitation has no tendency to a perpetuity.

Springing Uses, though often confounded with shifting uses, are more properly such as are limited to arise in a future event where no previous use is limited; as in the case of a bargain and sale to take effect ten years hence, where the use in the mean time remains in the grantor. They are subject to the same limits as shifting uses.

Future or Contingent Uses are properly such as are limited to take effect as remainders; such as a use to the first unborn son of A, after a limitation to him for life or for years determinable with his life. The rule of law, that a vested freehold must precede a contingent remainder, did not apply before the statute to contingent uses, because the freehold remained in the feoffees; but, since the statute, they are subject in this respect to the rules of contingent remainders. [Remainder.]

As the Statute of Uses was made previously to the Statute of Wills (32 & 34 Hen. VIII.), it has been questioned whether the former can be held to apply to the latter; but as, before the statute, devises of the use were permitted, so, since the statute, the courts have uniformly held that, where a devise is made to a use, the intention of the testator must be taken to be that the devisee of the use should have the legal estate.

By a construction of the Statute of Uses, adopted soon after it was passed, the grounds of which it is not easy to understand, it was settled that a use could not be limited on a use, that is, that the statute would operate on the first declaration of use only: so that if, by bargain and sale, a use in lands were limited to A and his heirs in trust, or to the use of B and his heirs, the statute would vest the legal estate in A without adverting to the use declared in favour of B. The Court of Chancery availed itself of this construction to revive Uses under the name of Trusts; and it was determined that A was, in the case above mentioned, a trustee for B of the beneficial interest in the land. It is not true, however, as has been said by Lord Hardwicke, that the Statute of Uses "has had no other effect than to add at most three words to a conveyance;" for the Court of Chancery, availing itself of its exclusive jurisdiction over trusts, and aware of the mischiefs attendant upon uses before the statute, has gradually established a system well adapted to answer the exigencies of family settlements and provisions, without producing any of those evils which the statute of Henry VIII. was intended to remedy. [Trusts.]

USES, CHARITABLE AND SUPERSTITIOUS. The term "Charitable Use," as understood in law, is of very extensive application, and includes dispositions of property which cannot with any propriety be described as charitable, but which are so called with reference to the purposes enumerated in the statute 43 Eliz., c. 4, or such as are considered analogous to them. That statute enacted that the Commissioners thereby empowered should inquire as to the lands, &c. given by well-disposed people "for relief of aged, impotent, and poor people; for maintenance of sick and maimed soldiers and mariners; schools of learning, free-schools, and scholars in universities; for repair of bridges, ports, havens, causeways, churches, sea-banks, and highways; for education and preferment of orphans; for or towards the relief, stock, or maintenance of houses of correction; for marriage of poor maids; for supportation, aid, and help of young tradesmen, handicraftsmen, and persons decayed; and for relief or redemption of prisoners and captives, and for aid or ease of any poor inhabitants concerning payment of fifteens, setting out of soldiers, and other taxes." Many gifts not within the letter have been held to be within the equitable construction of this statute; and when the gift is to charity in general, without any particular purpose being specified, it will be carried into effect either by the Crown or the Court of Chancery, upon principles which the determinations of that court have established. The term "Charitable Use," in law, is applied exclusively to gifts for what are called public charities, the objects of which are not particular individuals, but a class or the public in general.

A superstitious use, in its original sense, was where lands, tenements, rents, goods, or chattels were given, secured, or appointed for or towards any of the following purposes, namely: the maintenance of a priest or chaplain to say mass; for the maintenance of a priest or other man to pray for the soul of any dead man in such a church or elsewhere; to have or maintain perpetual obits, lamps, torches, &c., to be used at certain times, to help to save the souls of men out of purgatory. (See the 15 Rich. II., c. 5; 23 Hen. VIII., c. 10; and 1 Edw. VI., c. 14.) The statute of Richard II. was passed for the purpose of subjecting lands conveyed to uses to the law of mortmain. The statute of Henry VIII. relates only to assurances of lands to churches and chapels, which, if for a longer term than twenty years, it declares to be absolutely void. By the 1st of Edward VI. certain superstitious uses then existing were forfeited to the king, but the statute has no prospective operation. There is no statute making superstitious uses void generally, but the king, as head of the commonwealth, and as intrusted by the common law to see that nothing is done in maintenance or propagation of a false religion, was considered entitled to pray a discovery of a trust to a superstitious use, and to order the property to be applied to a proper use. The same principle has been applied to many cases of gifts of property for purposes which cannot properly be classed as superstitious uses, but are either expressly prohibited by the law of the country or contrary to its policy. A change in the doctrine of superstitious uses has been made by the 2 & 3 Wm. IV., c. 115, which puts persons professing the Roman Catholic religion upon the same footing, with respect to their schools, places for religious worship, education and charitable purposes, as Protestant Dissenters; with respect to whom the doctrine of the court is, that it will administer a fund to maintain a society of Protestant Dissenters promoting no doctrine contrary to law, though at variance with that of the Established Church. The 2 & 3 Wm. IV., c. 115, is retrospective. (2 M. & K. 225.)

The Court of Chancery has a general jurisdiction over property given for charitable purposes, and the regular mode in which matters relating to charities are brought before it is by information by the attorney-general on behalf of the crown.

The Court of Chancery adopts a very liberal construction of gifts for charitable purposes; and there are numerous cases of gifts for objects not within the letter of the statute of Elizabeth, which have been considered to be within the equitable meaning of the word charity as understood in that court, and have been administered accordingly. And when a gift is made for charity generally, without any purpose specified, if the gift be to trustees, the court will order a scheme to be prepared for the direction of the trustees in the administration of the trust; and where the declared object is charity, but no trust has been interposed, the right to dispose of the property, and to declare the particular charitable purposes to which it is to be applied, belongs to the crown by sign-manual. Where the particular objects which the donor had in view fail, either wholly or in part, the court adopts what is called the principle of administration *cy-pres*, that is, it directs the property to be applied to worthy objects in its judgment most nearly resembling those which have failed, or when more than one charity has been named by the donor, to such of the others as are still subsisting. When the revenue of the property increases from any cause, the increase goes to the charity, if it appear to have been the intention of the donor that the whole should be disposed of in that manner; otherwise the increase will go to the legal representative of the donor. In cases where the revenue of the property was distributable among several charities, the question has been, in what manner the increase of income was to be disposed of among them. The principle established by the cases seems to be, that a charity to which a fixed annual sum has been given has no right to participate in the increase, but that one entitled with the other charities to a proportionate part of the original income will have a right to a similar proportion of the increase.

When property is given to a superstitious use, or for a charitable purpose which the law will not allow to be carried into effect, the court, upon the not very satisfactory ground that the property was meant for a charity, will apply it to some other charity of which it approves. In the words of Sir William Grant, "Whenever a testator is disposed to be charitable in his own way and upon his own principles, we are not content with disappointing his intention, if disapproved by us: but we make him charitable in our way and on our principles. If once we discover in him any charitable intention, that is supposed to be so liberal as to take in objects not only not within his intention, but wholly adverse to it." (7 Ves., 495.) If the superstitious use be one which the court considers charitable, the fund goes to the king to be disposed of to such charitable uses as he shall direct by sign-manual: if the use be not charitable, the gift is merely void, and the property will go to the donor's representative. (2 M. & K., 684.)

The regular mode of proceeding in cases of abuse of charitable funds was until recently by way of information in the name of the attorney-general on behalf of the crown. But the act 16 & 17 Vict. c. 137, known as the Charitable Trusts Act, has, without abolishing the functions of the attorney-general with respect to charities, provided a regular machinery of commissioners and inspectors, whose duty it is to investigate all cases that may be brought to their notice, and to institute such proceedings as may be necessary for the rectification of abuses.

The jurisdiction of the Court of Chancery over property given to charity must be distinguished from the authority frequently exercised by the lord chancellor or lord keeper as visitor of charities. Charities are either under the management of individual trustees, or are established by charter as eleemosynary corporations. On the institution of a corporate charity, a visitorial jurisdiction arises of common right to the founder and his heirs, whether he be the king or a private person, or to those whom the founder has appointed for that purpose; and the office of visitor is to determine the differences of the members of the society, and to superintend generally the government of the body, in accordance with the statutes originally propounded by the founder. With this visitorial power the Court of Chancery has nothing to do, its right of interference being confined entirely to the administration of the property. When the charity is of royal foundation, the visitorial power of the king is exercised by the lord chancellor as his representative; and even where the founder of the charity was a private person, if he has made no appointment of a visitor, and if his heir cannot be discovered, or has become lunatic, the visitorial power, rather than that the charity should not be visited at all, results to the crown, and, as in the case of royal foundations, is exercised by the lord chancellor. The mode of application in these cases is not by way of information, but by petition addressed to the Great Seal.

Certain restrictions have been put upon the power of making gifts of property to charitable uses by the 9th of Geo. II., c. 36, commonly, though improperly, called the Mortmain Act. By it devises of land and bequests of money to be laid out on land or in any interest in land are declared void. For an explanation of the provisions of this act, see Mortmain.

USNEIN. [Lichens, Colouring Matters of.]

USNIC ACID. [Lichens, Colouring Matters of.]

USUCAPIO. Gaius (ii. 40-42) states that if a Res Mancipi was transferred by bare tradition, without the forms of Mancipatio or in Jure Cessio, the original owner retained the Quiritarian ownership, and the person to whom the thing was transferred had only the right to the enjoyment of the thing until by possession he had acquired the ownership (possidendo usucapiat). For the effect of such enjoyment was to give him the same rights with respect to the thing as if it had been transferred in due legal form. In the case of moveables the Twelve Tables fixed one year as the term of Usucapio; in the case of land and houses, two years. The acquisition of the Quiritarian ownership of a thing by enjoyment of it under the circumstances above stated for these several periods was called Usucapio.

Gaius states that there might also be Usucapio in the case both of things Mancipi and things Nec Mancipi which had been transferred by bare tradition from a person who was not the owner, provided the transferee received them in good faith (bonâ fide), or, in other words, believed that he received them from the owner. It seems probable that this rule of law was established by analogy to the rule of the Twelve Tables as to Res Mancipi which had been transferred by defective modes of conveyance. But the Twelve Tables may have fixed only the time of Usucapio: the origin of Usucapio may be anterior to the Twelve Tables.

When Gaius wrote (in the second century of our æra), Usucapio, as it appears, had become a regular mode of acquiring ownership; for property of all kinds might be so acquired which had been received by tradition and bonâ fide from a person who was not the owner. The case of things stolen, or the possession of which had been acquired by violence (vis), was an exception, for even if received bonâ fide they could never become the property of the receiver by Usucapio. The Res Mancipi of women also, who were in the tutela of their agnati, could not be objects of Usucapio unless they had been received from her by traditio with the proper consent (auctoritas) of her tutor: and the hereditas of a woman who was in tutela legitima could not be an object of Usucapio. As land (fundus) could not, according to the best opinion, be an object of furtum, a bonâ fide purchaser of land from a man who was not the owner, and knew he was not the owner, might acquire the property of it by Usucapio, provided the seller had not acquired the possession by violence, but had either taken possession of land which was vacant through the carelessness of the owner, or from the owner dying without a successor, or having been long absent.

Besides individual objects of property, Usucapio could exist in the case of Servitutes, and marriage, and in the case of an Hereditas. Originally such Servitutes as followed the rule of law as to Res Mancipi could only be transferred like Res Mancipi; and therefore Usucapio could only apply to such servitutes. But by analogy to Res Mancipi, they could be acquired by bare contract, to which Usucapio was superadded; and when Mancipatio at a later period was replaced by bare tradition, they could be acquired by contract simply. In the case of marriage, when there was no co-emptio, the woman might come into the power of her husband by virtue of uninterrupted cohabitation for one year; and she was then said to become a part of his Familia by Usucapio founded on a year's possession. (Gaius, i. 111.) In the case of the Hereditas, when the testator had not disposed of his property by the necessary forms of the Mancipatio and Nuncupatio, the person who was named heres in the will could only acquire his legal title as such by Usucapio.

These various instances will show the original notion of Usucapio. It was a legal effect given to bonâ fide possession and enjoyment for a fixed time, by means of which defects in the transfer of a thing were made good: it was not originally a mode of acquisition. It was founded on a title good in substance, but defective in form; and this defect was supplied by the proper period of enjoyment (usus). When this usus had continued for the legal time, it gave its auctoritas (as the Romans expressed it), its efficiency and completeness to what was in its origin incomplete; and the phrase Usus Auctoritas was older than the expression Usucapio, which was afterwards the ordinary term. But Usus by itself never signified Usucapio; for Usus alone could not give a title to the ownership of a thing. In the case of public land the possessor had the usus, but this was all that he could be entitled to as possessor. Such usus could not from the nature of the case have an auctoritas, for the possessor did not occupy the public land as a bonâ fide purchaser. A man might also have the usus of private land without having a title to anything further: in which case also the usus could never have an auctoritas. In the Roman law, as known to us in the Pandects, Usucapio appears as a mode of acquisition, which must have been owing to the circumstance of Mancipatio ceasing to be regarded as important: for bare tradition in all cases, followed by the proper usus, gave complete ownership. Finally, when the difference between Res Mancipi and Nec Mancipi was abolished, Usucapio in its original sense ceased. But as in the time of Gaius we find Usucapio applicable to the case of things Nec Mancipi, which a person had possessed bonâ fide, this rule of law still continued, and various limitations were in course of time established as to the mode of acquiring the ownership of a thing by the enjoyment of it. Thus Justinian, in his 'Institutes' (ii., tit. 6), after reciting the old law, refers to one of his Constitutions, by which the ownership of moveables might be acquired by use (usucapiantur), provided there was a bonâ fide possession (justa causa possessionis præcedente) for three years, and that of immovable things by the "longi temporis possessio," which he explains to be ten years "inter præsentes," and twenty years "inter absentes;" and the Constitution applied to the whole empire. Usucapio is defined in the 'Digest' (41, 3, 3) to be the "addition of ownership by the uninterrupted possession for a time fixed by law." As it was the addition of ownership, something is here implied to which this addition was to be made; and this something was a bonâ fide possession.

The subject of Usucapio admits and requires a much more complete exposition. The reader may refer to the following works: Engelbach 'Ueber die Usucapion zur Zeit der zwölf Tafeln,' Marburg, 1828; and Mühlenbruch, 'Doctrina Pandectarum.'

USUFRUCTUS, or USUSFRUCTUS, and USUS, belonged to the class of Servitutes Personarum among the Romans. Ususfructus is defined ('Dig.,' 7, 1, 1) to be "the right to use and take the fruits (fruendi) of what belongs to another without impairing its substance." Usus is defined ('Dig.,' 7, 8, 1, 2) to be the right "to use, but not to take the fruits (frui)."

The objects of ususfructus might be land (fundus), houses (ædes), slaves, beasts of burden, and other things. He who was entitled to a Ususfructus was called Usufructuarius, or Fructuarius. A right to a Ususfructus might be given to a person by testament, or it might be established by contract.

Generally, it may be stated that all the "fructus," or produce of a thing that accrued during the time of enjoyment, belonged to the Fructuarius; but his title to fructus was not complete till he had taken them, and it was a general rule that any "fructus" which had not been got in or taken at the time when the Ususfructus ceased did not belong to him. The law as to things that yield an increase, such as fruit-trees and animals, did not present many difficult questions. As to houses and lands, the questions were sometimes more difficult. The Fructuarius was entitled to the rents and profits of houses during his time of enjoyment, and he was bound at least to keep them in sufficient repair, but probably not to rebuild them, if they were in a ruinous condition. He was bound to cultivate land in a proper husbandlike manner. He could work existing mines and quarries for his benefit, and he could also open new mines and work them. The Fructuarius could maintain his rights to the ususfructus by actions and interdicts. The period of ususfructus might either be for a fixed time or for the life of the Fructuarius. At the termination of the period of enjoyment, the thing was to be given up to the owner, who could generally require security for its being properly used and given up in proper condition.

The usus of a thing, as already explained, was a right to the enjoyment of a thing, but not to the produce or profits of it. Yet in some cases the usus of a thing implied a right to a certain amount of produce. Thus the usus of cattle implied that the usuarius was entitled to a moderate allowance of milk; and a man who had the usus of an estate could take wood for his daily use, and could enjoy the orchard and other things in moderation. If a man had the usus of oxen, he could employ them for all purposes for which oxen are properly used. The duties of the usuarius resembled those of the fructuarius.

The rules of law which related to the ususfructus and usus were numerous. Many of them are collected in the 'Digest,' lib. 7; see also 'Fragmenta Vaticana,' 'De Usufructu;' and Mühlenbruch, 'Doctrina Pandectarum.'

USURPATIO is sometimes used by the Roman jurists in the sense of interruption of Usucapio. But the verb "usurpo" and its derivatives are commonly used in the sense of "using," or "employing," in any way that is suitable to the character of the object used or employed. The participle "usurpatus" sometimes signifies the acquisition of a right by use: thus "usurpatam mulierem" (according to the ordinary reading in Gellius, iii. 2) means a woman who had come into the power of her husband by uninterrupted matrimonial cohabitation for one year. (See Savigny, 'System des heutigen Römischen Rechts,' iv., ch. iii., § 183, on the passage of Gellius, which is a quotation from Q. Mucius Scævola, the pontifex.) The word is also used in the sense of taking possession of a thing; and in course of time the notion of wrong was attached to the word. Ammianus Marcellinus (xxvi. 7, ed. Gronov.) uses "usurpator" in a sense somewhat like the modern "usurper," when he says "usurpator indebitæ potestatis."

USURY. Although the legitimacy of interest upon moderate and conscientious terms has long been recognised amongst us, it has, until quite recently, been believed desirable to regulate by law the rate at which it should be taken, and interest beyond this allowed limit has long been stigmatised with the odious appellation of usury. [Interest.] It has been reserved for our own time to carry out a principle which political economists had preached for above a century, that of permitting the rate of interest to regulate itself according to the exigencies of the time and the nature of things. The first statute by which some relaxation of the usury laws was made in favour of trade, was the 3 & 4 Will. IV., c. 98, which enacted, that no person taking more than the rate of legal interest for the loan of money on any bill or note not having more than three months to run, should be subject to any penalty or forfeiture. Shortly afterwards the statute 5 & 6 Will. IV., c. 41, enacted that bills or other securities should not be void because a higher rate of interest than was allowed by the statute of 12 Anne had been received thereon. The statute 1 Vict., c. 80, next enacted, that bills payable within twelve months, should not for a limited time be liable to the usury laws, and this statute was followed by six others, extending from time to time the application of the original act. The statute 2 & 3 Vict., c. 37, enacted that no bill or note, payable within twelve months after date, or not having more than twelve months to run, nor any contract for the loan of money above 10*l.*, should by reason of interest taken thereon or secured thereby, or any agreement to buy or receive or allow interest in discounting, negotiating, or transferring any such bill or note, be void, nor any person so lending be liable to the penalties of the usury laws; but it was provided that this relaxation should not extend to the loan or forbearance of any money on the security of land. The public mind having thus slowly advanced in the direction of the policy advocated by Bacon above two centuries ago, at length became prepared for a still wider measure, and the statute 17 & 18 Vict., c. 90, after laconically reciting in the preamble, that "it is expedient to repeal the laws at present in force relating to usury," proceeds to repeal wholly, or in part, eleven English, five Scotch, and four Irish acts, on which the whole penalties of usury previously rested: among these acts are included those relating to annuity transactions. [Annuity.] The natural laws which regulate the terms on which money can be borrowed are, therefore, now left to operate freely, and borrowers and lenders are amenable to no other rules than those which govern contracts in general.

(Blackstone's *Commentaries*, Mr. Kerr's edition, vol. ii., p. 475.)

UT. [Gammut.]

UTRECHT, TREATY OF. [Treaties, Chronological Table of.]

UVA, *Uvæ papæ*. The former is the name of the fruit of the vine, in the natural state of grape, the latter when the grapes have been spread out and dried, and so made *raisins*. Currants are a peculiar kind of grape dried. The chief employment of *raisins in medicine* is to flavour unpleasant mixtures, or for their demulcent properties. In the former point of view they are unimportant; in the latter, of considerable utility. Fresh grapes are cooling, aperient, moderately nutritive, and demulcent. Their use in the south of France is thought to contribute greatly to the amelioration which consumptive persons experience there, and in some instances their effect is so striking as to have given rise to the term *cure de raisins*. The dried fruit is less acid, but more nourishing, and more demulcent. It possesses all the soothing qualities of jujube, and is much cheaper. It may be easily made into a conserve by removing the seeds and beating the pulp into a thick mass. For persons with irritable throats and liable to winter coughs, a portion of this put into the mouth before going into the open air is an excellent protective measure, and often prevents cough, which, when once excited, it is difficult to allay. An excellent demulcent drink is made from a compound of barley and raisins. Currants contain more acid than common raisins, and should be preferred where an aperient action is desired. Much tannin of a very pure kind is also contained in the pits of the seeds. This may render the seeds astringent; but for consumptive persons it is best to remove the seeds from the grapes, at all events not to swallow them, as their very indigestible nature may irritate the bowels and cause diarrhœa, a formidable symptom in consumptive persons.

An oil exists in the seeds of the grape, in the proportion of 12 pounds of oil to 100 pounds of seeds. Though it is not obtained without difficulty, it is extracted in Italy in large quantity. When heat is used, it has a harsh taste, and is mostly used for burning; but when cold-drawn, it may be used for food.

USUS. [Usufructus.]

V

V, as pronounced by the English, is the pressed or medial labial aspirate, bearing the same relation to *f* that *b* does to *p*. Its form is only a variety of the character by which the vowel *u* is denoted, the latter being in its origin the cursive character employed with soft materials, while *v* is better adapted for writing on stone. The Roman letter *v* was probably pronounced as a *w*, a supposition which would explain the fact that in the alphabet of that language one character is employed for both *u* and *v*. The converse of this appears in the German alphabet, where *w* has nearly the power of *v*, while the latter symbol is used to designate the sound of the English *f*, as is the case also in Welsh.

v is interchangeable with *b* and *m*: see these letters. It is also interchangeable with *f*, and hence the confusion between the characters, as just observed. The changes with *w*, *gu*, *du*, will be considered under the letter W.

VACCINATION. [Small Pox; Jenner, in Biog. Div.]

VACCINIC ACID. This name was applied to an acid substance extracted from butter, but it is now believed to be merely a mixture of butyric and caproic acids.

VACUUM, or VOID, the name given in physics to the idea of space wholly free of matter, or perfectly empty. In the common phrase, space is called empty when, so far as air can fill space, it is full of air; and even in a more scientific form of speech, there is said to be a vacuum when there is only such an approach to a vacuum as the operations of philosophy can procure. Thus in the *vacuum* of the air-pump, however long the attempt at exhaustion may be continued, there is always air left, though in a highly attenuated state; and even in the mercurial vacuum, or in the space which is left over the mercury of the barometer, there is not unfrequently a slight portion of air, and always an atmosphere of the vapour of mercury. Physically speaking, it is perhaps impossible to procure a vacuum: it is most likely that, even if a real vacuum could be procured for an instant, air or other vapour would at once begin to be disseminated from the sides of the vessel in which the vacuum was made and that the vacuum would thus instantly cease to exist.

But the question of the existence of vacuum, in its strict and absolute sense, and as to whether such a thing were possible or not, was a subject of controversy from before Aristotle to after Newton. It was meant, like other questions of physics, to receive its solution from the exercise of the intellect employing itself upon the apparent properties of material bodies. Aristotle and others denied the actual existence of a vacuum, from a want of exact knowledge of the laws of motion. In a vacuum, says Aristotle ('Physic.,' l. iv., c. 8), there would be no reason why motion should be to one part rather than another. He apparently attributes all motion to the pressure of adjacent matter, not only in its commencement, but in its continuance. A modern philosopher would say that, even if the creation of a vacuum destroyed the cause of gravitation, still a body falling downwards into a vacuum would move through it with the velocity which it had at its entrance. Democritus, Epicurus, and others, assert the existence of a vacuum; and most of the different sects among the Greeks seem to admit the possibility of such a thing, though some of them deny its actual existence.

Descartes denied the very possibility of a vacuum, and upon such grounds as will make most persons feel that if Newton had not come, it would have been better to have kept to Aristotle. There is in his writings an absolute and palpable confusion between *space* and *matter*, to the extent of an assertion that the destruction of all the matter in a certain space would be the destruction of the space itself. He places the essence of matter in the occupation of space, and thence infers by a wrong conversion that there cannot be space without substance (by which he means matter). As follows: "Vacuum autem philosophico more sumptum, hoc est, in quo nulla plane sit *substantia*, dari non posse manifestum est ex eo quod extensio spatii vel loci externi, non differat ab extensione *corporis*. Nam cum ex eo solo quod corpus sit extensum, rectè concludamus illud esse substantiam; quia omnino repugnat ut nihili sit aliqua extensio; idem etiam de spatio quod vacuum supponitur, est concludendum: quod nempè cùm in eo sit extensio, necessariò etiam in eo sit substantia." ('Principia Philosophiæ,' part ii., § 16.) "So that," he proceeds (§ 18), "if God were to destroy all the matter (corpus) in a certain vessel, and to permit no other to come into the *place* of it (locum ablati), the sides of the vessel would be contiguous; *for* when nothing (nihil) comes between two bodies, they must touch each other." Matter and space are both things; but Descartes falls into the extraordinary confusion of ideas which is implied in first adopting the common sense of the word nothing, as when we say a vacuum is full of nothing, and then arguing from the strict meaning of the word "nothing," and denying that "nothing" can have extension. It is not true, properly speaking, that there is "nothing" in a vacuum, for the very notion of a vacuum is *space* void of matter.

The idea of Descartes on the essence of matter was carried by his followers to the full extent of using matter as a synonyme for extension. Le Grand says that a vessel filled with gold has not more matter than one filled with water. There is more weight, he says, more hardness, &c., but not therefore more matter; for the essence of matter is not in weight, nor in hardness, &c., but in extension. And he objects to the adage that "Nature abhors a vacuum," because he considers such an assertion merely to amount to saying that Nature abhors a contradiction in terms. Newton ('Principia,' book iii., prop. 6, cor. 4) expresses his opinion of the vacuum question in this way: "If all the solid particles of bodies are of the same density, so that rarefaction cannot take place without the creation of pores, there must be a vacuum." Since matter is of different density in different substances, and since the same substance may be compressed into smaller space or expanded into larger, it must either be that the solid particles are contracted or expanded, or that vacuous pores exist. This alternative does not do much. A person trained in the sciences as they now exist, thinks the idea of *solid* matter (that is, entirely solid, without any vacuum) being compressed into more solid matter, to be most incongruous and improbable; but impressions derived from habits are not arguments. The strong part of the Newtonian argument arises however from the results of the planetary theory. These celestial bodies have moved, during two thousand years of recorded observations, with exactly the same mean motions as at present, which they could not have done if they had moved in a medium of any sensible resistance. If then the celestial spaces be full of matter, it is matter of such a degree of tenuity that two thousand years is not enough to make it show any visible effect in altering the planetary motions. But again, though this argument has, almost up to the present time, induced astronomers to suspect an absolute vacuum, yet very recently the feather has shown a resistance which was not manifest against the guinea. A comet has been strongly suspected—all but proved—to be undergoing precisely the same sort of change in its mean motion which it is known would result from a resisting medium. [Comets, col. 68.] The undulatory theory of light, moreover, which is now pretty generally received, supposes the whole of the celestial spaces to be filled with the luminiferous ether. The astronomical argument, therefore, in favour of *absolute* vacuum has fallen; but the views of the constitution of matter which have grown with the rise of the molecular sciences of chemistry, light, heat, electricity, &c., have supplied its place with much more effect. We cannot enter into the various probabilities in favour of the molecular theory, which supposes matter to be atomic, the atoms being perhaps separated by distances which are many times their own diameters. If any one were to assert that the densest substance has in it many millions of times more of vacuity than of solid matter, the assertion could not be disproved, nor even shown to be improbable. "There are difficulties," said Dr. Johnson, "about a *plenum*, and there are difficulties about a *vacuum*, but one of them must be true;" that is, either all space is full of matter, or there are parts of space which have no matter. The alternative is undeniable, and the inference to which the modern philosophy would give the greatest probability is, that all space is *full* of matter in the common sense of the word, but really occupied by particles of matter with vacuous interstices; showing all degrees of density, from that of the ether of light, which is wholly unappreciable, to that of hammered platinum, which is twenty-two times as heavy as water.

Probably the manner in which the reader is most familiar with the use of our leading word is in connexion with what he may have seen written on the maxim which we have already quoted—"Nature abhors a vacuum;" a doctrine which, though common among the followers of Aristotle, must not, any more than many others, be therefore taken as emanating from that philosopher himself. This is usually cited as a proof of the puerility of the ancient and middle philosophy—we think, somewhat unjustly. The personification of Nature is common to all times, and we are in the habit of saying that Nature exhibits phenomena, conceals her operations, uses the simplest means, &c. Now Nature may as well abhor, as exhibit, conceal, or employ; and where intelligence is understood, all who use the word Nature mean the God of Nature: while when the mere operations are referred to, Nature is only the personification of the collective body of second causes. As the statement of a fact, it is *true:* Nature *does*, to the best of our knowledge, abhor a vacuum; *she* (if we may personify her) never suffers it to exist to the extent of allowing any space which is perceptible to our senses to be vacuous. But if the adage were meant to supply a reason for the fact, those who used it were deceiving themselves, but not so that the most of those who would laugh at them would have any reason in their mirth. It is the error of every period to use words expressive of a fact observed in the sense of assignment of a reason for that fact; and the centuries which have always been ready with their *fluids* to stand for the causes of heat, electricity, magnetism, &c., should not be too hard upon the preceding ages, which put the feelings of nature in the place which they rather prefer to occupy by hypothetical gases. The very word attraction [Attraction], in the sense generally assigned to it, is precisely of the same nature as the natural *abhorrence* of the Aristotelians: namely, a word invented to supply the place of a cause. Those who can use the former word in a really philosophical sense are precisely those who can see that some of the ancients may have done the same with the latter.

"The question of the existence of vacuum, in its strict and absolute sense," to repeat the designation given in the preceding portion of this article, which is reprinted as it originally appeared, on account of its historical and philosophical value, is inseparable from that of the nature of space. If space, as suggested in a former article [Physical Forces, Correlation of, col. 496], be "the extension of material substance, the resultant of its dimensions, and mere consequence of its existence," an absolute vacuum is in the nature of things impossible. But the admission of the existence of space distinct from matter is equivalent to affirming the existence of an absolute vacuum. Space distinct from matter is nothing else. This subject, however, resembles others of what may be termed transcendental natural philosophy, such as the (alleged) infinite divisibility of matter or of space, the absolute zero of heat, &c. The affirmative of each is purely imaginary, being something which is mentally conceived to be abstractedly and intrinsically possible, without any reference to known physical facts, which are gratuitously assumed, not in reality to define and limit the subjects, but to depend altogether, in relation to them, on the necessary imperfections of the senses and of our finite condition. But neither by observation or experiment, nor by mathematical reasoning from either, do we know anything about space distinct from matter, about the infinite division of matter, or about the existence of anything but at some temperature or amount of heat in the state or condition in which it causes expansion. (The calculations which have been made as to the number of thermometric degrees between some known temperature and the supposed absolute zero are entirely nugatory, and unworthy of attention. There is no more reason to believe in the existence of an absolute zero than in absolute rest, or in a limit to space, or than to believe, for philosophical reasons, in the cessation of phenomena, or in the beginning or the end of time.) And these three subjects —the alleged absolute vacuum, infinite division of matter or of space, and absolute zero or its converse—are as inseparably connected in mental conception, as are the physical types of which they are abstractions in observed fact.

To divest the subject of a notion introduced—we think unnecessarily—into modern discussions on the divisibility of matter, we must here premise that absolute vacuum and empty space, or space distinct from matter, being the same thing, it is clear that there can be no infinite division of space; while, by hypothesis, so far as our argument has yet advanced, there may be infinite division of matter. But admitting space to be the property of matter, its divisibility is the same thing as that of matter, and the possibility of that divisibility must depend on that of matter itself.

This being premised, we return to the main union of subjects before us. The mental conception of an absolute vacuum is in reality incompatible with that of the infinite division of matter and of the absolute privation of heat; though, remarkably, some philosophers, and even modern men of science, have affirmed the second and third (the two latter) and denied the first, while others, also, have denied the first and third but admitted the second. If, again, matter be infinitely divisible, there can be no absolute zero, since everything must exist at some temperature, which, in fact, is as inseparable from material existence as space and time themselves. If there were an absolute zero, matter could not be infinitely divisible, for there would be (an inferior) limit to its expansibility.

But, on the other hand, the idea of the only finite divisibility of matter does not imply that of an absolute zero, though it is the only notion of divisibility compatible with it; because the finite particles of matter, like the masses they compose, must be susceptible of indefinite reduction of temperature, if they retain the character of matter.

We must descend, however, from these views to the observed facts from which we believe they are necessary inferences. The sum of our actual knowledge, whether exclusively experimental or also inductive or deductive, is, that something (but not everything) exists everywhere; that everything exists in some place—that is, in, or is, some part of space, is of some magnitude and of some temperature, and that nothing is at rest—that is, that the place of everything is always changing. In absolute truth these are, we believe, if not identical propositions, yet such as involve each other, though to prove this would require greater length than we can now command.

In the present era of physical science, that inaugurated, in certain directions, by the successive labours of Volta, Davy, Oersted, Seebeck, and Faraday, a belief that the intervention of material particles is necessary for the transmission of any kind of force, and therefore that no force does or can operate through unoccupied space or vacuum, has gradually, but, until a comparatively late period, as it were silently, grown up. The force of the evidence which had accumulated, however, appears not to have been recognised until after the appearance (in the 'Philosophical Transactions' for 1835-1838) of Dr. Faraday's experimental researches on electrical induction. We have been of opinion, from the time of their publication, that these in reality involve the demonstration of the impossibility of distant action, and therefore of the necessity of the intervention of particles by which the action may be and is transmitted from one acting body to a distant one; and it is certain that the awakening of the attention of philosophers to the true condition of the subject involved, dates from about that time.* This result is of course fatal to the admission of a true physical vacuum. It is remarkable that this result had been clearly anticipated by Newton himself, who held that the planetary spaces could not really be vacuous because they were traversed by the force of gravity. This remarkable expression of Newton's sagacity and power of thought has had a singular fate. Recorded in 1693, it remained unpublished for nearly a century, when it appeared (in 1783) in Horsley's edition of his works. But it seems to have remained unregarded until it was brought forward by the celebrated Professor Playfair, so late as the year 1819—more than a century and a quarter after its original enunciation—and that merely for the purpose of proving "that Newton did not consider gravity as a property inherent in matter." But even Playfair did not perceive the entire force of the passage, and, indeed, the light which electricity was destined to throw on all branches of molecular physics had not then been received; Faraday had not yet replied to Playfair's question, "it is not quite clear in what manner the interposition of a material substance can convey the action of distant bodies to one another." † A third part more of a century was destined to elapse, when Faraday cited Newton's expression, to the general surprise of the scientific world, in one of his discourses at the Royal Institution, in 1853, in order to show that Newton "was an unhesitating believer in physical lines of gravitating force," and must be ranked "amongst those who sustain the physical nature of the lines of magnetic and electrical force." ‡ The irreconcilability of the conception of lines of physical force with that of an absolute vacuum, identifies the subject now reviewed with that of the present article.

We proceed to notice some modern and comparatively recent experimental investigations, involving the production of nearer and nearer approximations to a physical vacuum, or the more and more complete removal of ponderable matter from an inclosed space. It is matter of this kind only, the quantity of which, in a given space, can at all be diminished; that of the matter of a higher order, the ether which manifests and transmits heat and light and perhaps magnetism, according to our present experimental means, cannot be affected; though apparently acted upon in a certain mannner by the molecules of ordinary matter, it cannot be confined or diminished in amount, any more than it can be measured or weighed. Or,—to express this in terms independent of theory,—a vacuum transmits light and heat, diminished only by the imperfect transparency and transcalescence of the including vessel. In the investigation in question, more or less perfect vacua have been obtained by the air-pump; others on the principle of the space void of air left above the mercury in the barometer, called the Torricellian vacuum; some by the combination of both these means; and others again by the union of one or both with chemical agency, by which apparently the most perfect vacua have been produced.

Dr. Thomas Andrews, F.R.S., Vice-President of Queen's College, Belfast, whose refined physico-chemical researches have required the use of the nearest approach to a perfect vacuum in which certain instruments could be observed, has devised a method of obtaining probably a more perfect air-pump vacuum than had before been produced. He characterises the Torricellian as the nearest approach to a perfect vacuum which at the time when his method was devised had been obtained. "It is true," he remarks, "that it contains a little mercurial vapour at the ordinary temperature of our summers, and probably also at lower temperatures, but the quantity is exceedingly small, and its influence in depressing the barometric column must be altogether inappreciable. Besides the mercurial vapour, a trace of air may generally be detected." Dr. Andrews shows that it is easy to calculate approximatively the depression of the column produced by this; and he finds that if the diameter of the bubble be 0·02 inch, the pressure of mercury under which it has been measured 2 inches, and the volume of the space above the mercury when the tube is vertical 1·2 cubic inch, the depression of the mercurial column is nearly 0·00001; "or the depression of the mercury, in consequence of the vacuum not being absolutely perfect (with respect to air), amounts only to $\frac{1}{100,000}$ of an inch. It is easy in actual practice," Dr. Andrews continues, "to realise this close approximation to a perfect vacuum," and the quantities he stated, he says, apply to a barometric tube employed in an experiment he subsequently describes. Observing, however, that the Torricellian vacuum is unfortunately applicable to very few physical investigations, as no instrument of any kind can be introduced into it, nor even any substance which is acted upon by mercury, and noticing the imperfection of the ordinary air-pump and of M. Regnault's method of pushing the exhaustion further after the valves have ceased to act he proceeds to describe, in the following terms, a process by which, with very little trouble, a vacuum may be obtained in the ordinary receiver of an air-pump, so perfect that the residual air exerts no appreciable elastic force.

"Into the receiver of an ordinary air-pump, which is not required to exhaust further than to 0·3 inch, or even 0·5 inch, but which must retain the exhaustion perfectly for any length of time, two open vessels are introduced, one of which may be conveniently placed above the other; the lower vessel containing concentrated sulphuric acid, the upper a thin layer of a solution of caustic potash, which has been recently concentrated by ebullition. The precise quantities of these liquids is not a matter of importance, provided they are so adjusted that the acid is capable of desiccating completely the potash solution, without becoming itself notably diminished in strength, but at the same time does not expose so large a surface as to convert the potash into a dry mass in less than five or six hours at the least. The pump is in the first place worked till the air in the receiver has an elastic force of 0·3 or 0·4 inch, and the stop-cock below the plate is then closed. A communication is now established between the tube for admitting air below the valves, and a gasholder containing carbonic acid, which has been carefully prepared so as to exclude the presence of atmospheric air. After all the air has been completely removed from the connecting tubes by alternately exhausting and admitting carbonic acid, the stop-cock below the plate is opened. and the carbonic acid allowed to pass into the receiver. The exhaustion is again quickly performed to about the extent of half an inch or less. If a very perfect vacuum is desired, this operation may be again repeated; and if extreme accuracy is required, it may be performed a third time. It is not likely that anything would be gained by carrying the process further. On leaving the apparatus to itself, the carbonic acid which has displaced the residual air is absorbed by the alkaline solution, and the aqueous vapour is afterwards removed by the sulphuric acid. The vacuum thus obtained is so perfect, that even after two operations it exercises no appreciable tension."

Even after this limit has been reached, the exhaustion may be pushed still further, "till it must become at last not less complete than the Torricellian vacuum; while at the same time by suppressing the manometer, the existence of mercurial vapour may be altogether prevented. The manipulation required to arrive at this result will not interfere with the presence of even the most delicate instruments in the receiver." In an experiment which Dr. Andrews describes, the theoretical residue of air would be $\frac{1}{135,000}$ of the entire quantity in the receiver, which would cause a depression of $\frac{1}{4500}$ of an inch only, and this, he says, must have been nearly realised. Such a vacuum has remained without the slightest change for fourteen days. 'Phil. Mag.,' Feb., 1852; 'Quart. Journ. of Chem. Soc.,' vol. v., p. 189-192.

Unless the still more perfect carbonic-acid vacua employed by Mr. Gassiot, and about to be described, should be obtainable in comparatively large vessels adapted for the observation of instruments, &c., —towards which result, indeed, Mr. Gassiot has made some approach, —Dr. Andrews's method appears to be the most eligible for the generality of exact researches for which a vacuum is required.

In a paper 'On the Electrical Phenomena exhibited in Vacuo,' by Sir H. Davy, in the 'Philosophical Transactions' for 1822, he relates some experiments which he made for the purpose of elucidating "the relations of electricity to space, as nearly void of matter as it can be made on the surface of the earth." He repeated the electrical experiments with the Torricellian vacuum of Morgan and Walsh, and instituted others with similar vacua above a difficultly fusible amalgam of mercury and tin, and above fused tin. With the results as bearing on the theory of electricity we are not at present concerned; but these approximations to vacuous space were, of course, in reality, atmospheres of the vapours of the metals employed, though of excessive rarity; and a calculation made by Mr. Babbage for the author may be cited, as indicating how minute must have been the quantity of matter which they contained—how great must have been its "attenuation," in the language of the present day—which is a point of information important to the subject of this article. Considering the elastic force of vapour of water at 52° to be equal to raise by its pressure about ·45 of an inch of mercury; the relative strengths of vapour will be, reckoning the boiling points all from 52°, for mercury at 600°, ·000015615, ... and for tin, at 5000°, 37015, preceded by 48 zeros. The data on the diminution of the density of vapours by diminution of temperature supplied in this case by the chemist to the mathematician were probably in some degree erroneous, and the results would be affected by the limit to vaporisation for every substance at a certain temperature which Faraday, a few years after, rendered so highly probable, if not certain, but the latter would operate to diminish the density of the metallic vapours in question; and we may, all things considered, accept these numbers as fair expressions of the minute quantities of matter they are intended to represent.

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* See a critical notice of Faraday's 'Exp. Res.' in 'Phil. Mag.,' June, 1839, ser. iii., vol. xiv., p. 469.

† 'Second Dissertation on the Progress of Mathematical and Physical Science;' Supplement to 'Encyclopædia Britannica,' vol. iv., p. 83, note; 'Ency. Brit.,' 8th edit., vol. i., p. 684, note.

‡ How important to the progress of the science of physical forces this calling the attention of philosophers to Newton's views has really been, will appear from the following extract from the 'Theory of the Force of Gravity,' by Professor Challis, published in the 'Philosophical Magazine' for December, 1859, p. 442. "The *actio in distans* has been so long and so extensively regarded as an ultimate principle, and not as a temporary hypothesis admitting eventually of explanation, that it requires some degree of moral courage to maintain a different theory. Science, in my opinion, is much indebted to Professor Faraday for having recently directed attention to the opposite views entertained by Newton on this point, and for giving expression to analogous ideas of his own. (See the Lecture on the Conservation of Force, in the 'Phil. Mag.' for April, 1857, vol. xiii., p. 232.)" The lecture referred to was delivered in the preceding February; but Faraday, as we have seen above, had originally directed attention to Newton's views in 1853; and he regarded their importance as so great, that he had recalled them also in his discourses of the two following years.

Mr. Grove ('Phil. Trans.' and 'Phil. Mag.,' 1852) having originally observed a peculiar striation in electric discharges taken in a well-exhausted air-pump receiver, apparatus in some respects similar to that employed by Davy has been constructed by Mr. Gassiot, for the further investigation of that phenomenon as observed in Torricellian vacua, and partly by means of a process devised by the late Mr. John Welsh ('Phil. Trans.' 1856, p. 507), he has produced more perfect Torricellian vacua than any before obtained. 'Phil. Trans.,' 1858, pp. 3, 5.

In the continuation of the researches which these experiments of Mr. Grove and Mr. Gassiot initiated, the united science and ingenuity of several physicists, chemists, and mechanicians, have produced vacua still more perfect, that is, still more devoid of ordinary or ponderable matter; more strictly again, spaces in which a smaller amount of such matter existed than in any obtained before, and probably greatly exceeding in this respect the most perfect Torricellian vacua previously experimented with by the old electricians, and by Davy, as well as those first employed by Mr. Gassiot himself. For the purpose of obtaining them, a method has been adopted, often indicated, and to a certain extent employed, in chemical and physical research, but now pursued with much greater care and refinement, and with all the resources to ensure accuracy which the most delicate operations of modern chemistry can supply. The vacuum tubes to which we now allude appear to have been first constructed about 1857, by M. Geissler, of Bonn, and the vacua obtained by an application of the method alluded to, but which, it is understood, he has not precisely explained. Mr. Gassiot, desirous of knowing, during the progress of the experimental research upon which he had entered, the exact conditions under which each particular vacuum had been obtained, and finding that there was some uncertainty in the description of those he had obtained from M. Geissler, employed Mr. Casella to construct above 100 new tubes, each of which, however, was charged and exhausted by himself or in his presence. Each tube was filled, in the first instance, with atmospheric air, hydrogen, oxygen, or nitrogen, then exhausted by a good air-pump; another supply of air or of gas admitted, and the tube again exhausted; after the repetition of this process two or three times, mercury was introduced, and the tube finally exhausted as a Torricellian vacuum, and lastly hermetically sealed; the attenuated medium within thus being mercurial vapour, plus the remains of air or of the gas with which the tube had been originally filled.

Tested by the appearance of the electrical discharge from the Ruhmkorff inductive coil, found by Mr. Gassiot in these researches to be the most delicate of all tests of the presence of ponderable matter, these vacuum-tubes were at length ascertained to be void even of the slightest trace of air or gas, mercurial vapour alone remaining. But the progress of the investigation required that this also should be removed, and a still nearer approach to empty space obtained. This was effected by a refined modification of Dr. Andrews's process already described, suggested by Dr. Frankland; tubes, into which caustic potash had been introduced, being repeatedly filled with carbonic acid and exhausted; finally exhausted to the utmost limit of the capability of the air-pump, and sealed. These were found, on the application of the electrical test, to be far more perfect vacua than the Torricellian, and when the infinitesimally rare included atmosphere of carbonic acid gas was exposed to the action of a large surface of hydrate of potash, the vacuum no longer permitted the electrical discharge to pass, a result first obtained by Mr. Gassiot, and in these researches; when the potash was heated, more ponderable matter being diffused in the tube, the discharge again passed; but on allowing it to cool, the tube resumed its insulating state. These results were given by a tube 40 inches long and 1¼ inch internal diameter. An excellent carbonic-acid vacuum was obtained by the same method in an egg-shaped vessel, 22 inches long and 7 inches in its greatest diameter; but this did not insulate the discharge,—judging from the appearance of which, this vacuum may be inferred to be about equal, though in so large a vessel, to the best Torricellian vacuum in comparatively narrow tubes. The minute fraction of ponderable matter present does not appear to have been calculated in any of these instances. This is the nearest approach to a true physical vacuum that science has yet succeeded in producing. Mr. Gassiot concludes his paper with the remark—adopting a suggestion made by Mr. Brayley—"The fact that a vacuum so perfect can be obtained in a closed vessel containing such a substance as hydrate of potassa, would excite a hope that the limit to vaporation (vaporisation), the existence of which Faraday and others have, if not proved, at least rendered so probable, may be determined, and even its consequences exhibited by direct experiment." ('Phil. Trans.,' 1858, p. 157.)

Such is the present condition of this subject, one of the most interesting and most extensive in its philosophical applications which can claim the attention of the physicist and the chemist. The bearings of Mr. Gassiot's results, and of those obtained by other experimenters with similar apparatus, on the nature and theory of electricity, however important, are foreign to the object of this article. But the terms in which they have been described and the reasoning which has been founded upon them, involve a subject which is strictly within its scope. We conceive that the true and immediate induction from these results, is, in general terms, that in consequence of the diminution in density of the media through which the electricity has to pass—that is, of the diminution of the quantity of matter contained in a given space—certain properties of electricity are exhibited in a manner which a denser medium precludes it from manifesting: that this takes place up to a certain point of rarefaction, through which, if electricity can pass at all, greater intensity is required; or it may even be that a vacuum absolutely free from ponderable matter, which luminous electricity requires for its production and convection, has been temporarily obtained. Considering the nature and circumstances of the vessels and materials by which only it can be obtained, it must necessarily be temporary only. But the results have been described and reasoned from (originally, we believe, on account of certain views respecting the nature of matter entertained by Mr. Grove, to which we have elsewhere adverted), as if they depended, not on the removal of ponderable matter, but on its presence in an increased degree and with increased causation of phenomena. But in proportion to the completeness with which such matter is removed from an inclosed space, the ether which it still contains will be more free to exhibit its peculiar properties, unimpaired by the presence of an inferior and grosser form of matter; and the phenomena which have been attributed to "attenuated (ordinary) matter," ought, we conceive, to be ascribed to the unincumbered ether which remains. The fact that a certain amount of ordinary matter is essential to the manifestation of any sensible effects whatever by the electricity does not militate against this conclusion. It should be so. The conduction, or the convection by induction, of electricity belongs to ordinary matter, while the reception and transmission of impressions from it in the form of light and heat, belong to the higher order of matter, the ether.

VAGABOND. [Vagrant.]

VAGRANT. This term, which in its etymological meaning simply denotes "a wandering person," is obviously derived from the Latin *vago*. It was probably introduced into our law language from the Norman French; the phrase "*vagerantz de lieu en lieu curran̄tz per paiis*" occurring in our early statutes in the sense in which the word "vagrant" is used in common language at the present day. (Stat. 7 Ric. II., c. 5.) The persons to whom it is applied in ancient documents are usually classed with "faitours," (a word of doubtful origin, but meaning an idle liver or slothful person: Cowell's 'Interpreter;' Kelham's 'Dictionary,') "travelyng-men," and "vagabonds." The latter expression, "vagabundus," was known throughout Europe in connection with feudal law, and is interpreted to mean "crebro vagans, cui nec certum domicilium, nec constans habitatio est." (Calvini 'Lexic. Jurid.') It was used in this sense in English law as early as the reign of Henry II. (Cowell's 'Interpreter.') Modern laws have however given to the word "vagrant" a much more extended meaning, in the application of which the notion of wandering is entirely lost.

In the course of the transition made by the lower classes of society from the condition of feudal villeins to that of free labourers, vagrancy and mendicity necessarily ensued from the unsettled state of the poor; and in most countries where feuds had prevailed, severe laws were made to repress the evils which sprung from this source. In England various statutes and ordinances passed from time to time to obviate the inconveniences arising from wandering mendicancy. The earliest of these was a statute of ordinance, made in the 23rd year of Edward III. (1349), commonly called the Statute of Labourers, which, after reciting that "many sturdy beggars (validi mendicantes) were enabled by the gains of begging to live, and to devote themselves to pleasures and sins, and sometimes to thefts and other crimes," forbade "all persons, on pain of imprisonment, to give anything under colour of piety or charity to such as were able to labour." In 1366 there is a petition of the Commons complaining of wandering artificers and servants becoming beggars in order to support an idle life, and praying that it might be forbidden under a penalty for any one to give alms or sustenance to any such idle beggars; and that they should be apprehended and put in the stocks or sent to jail until they found surety for their return to their own country. ('Rolls of Parliament,' vol. i., p. 340.) The answer to this petition does not appear: but a few years afterwards a statute was passed making it (almost in the language of the petition) penal for artificers, servants in husbandry, and others, without a special licence, to quit the town, hundred, or wapentake in which they lived, to live and work in another town, hundred, or wapentake; and persons found vagrant (*vagarant*) without such licence might be placed in the stocks and imprisoned by the local authorities, until they found security for their return to the place to which they properly belonged. (Stat. 12 Ric. II., c. 3.) It was also enacted that "those who were able to work and went begging should be dealt with as persons travelling without a licence, and that beggars unable to work, dwelling in cities or towns, should remain in such cities or towns; that if such cities and towns were unable to support them, they should be taken to other places within the same hundred or wapentake, or to the place of their birth, and there remain during their lives." (Stat. 12 Ric. II., c. 7.) And it was probably upon the principle declared by these laws, that in the 15th century it was held to be lawful for any person to arrest and send to jail a man "found wandering (*vagarant*) in such manner that it is unknown how he gets his living." ('Year Book,' 9 Edw. IV., c. 27.) A statute which was passed in 1494 declared that all "vagabonds, idle and suspected persons, should be set in the stocks three days and three nights, and have none other sustenance but bread and water, and then should be put out of the town; and that whosoever should give such idle persons more should forfeit 12 pence; and that every beggar not able to work should resort to the hundred where he last dwelt, was best known, or was born, and there remain, upon the pain aforesaid." (Stat. 11 Hen. VII., c. 2.) This vague enactment was followed by the more definite provisions of the stat. 19 Hen. VII., c. 12, which declared that impotent beggars should go to and abide in the city, town, or hundred where they were born, or else the place where they had made their last abode for three years; and this rule of settlement was adopted in the statutes subsequently passed against vagrancy in the reigns of Henry VIII., Edward VI., Mary, and Elizabeth. (Nolan's 'Poor Law,' chap. xv.) By stat. 22 Hen. VIII., c. 12, the justices of the peace in every county were empowered to grant licences under seal to "poor, aged, and impotent persons," to beg within a certain precinct; and persons begging without licence or out of their precincts were to be whipped or set in the stocks for three days and three nights, with bread and water only. This provision applied to impotent vagrants. On the other hand it was provided that if any person, "being whole and mighty in body," and able to labour, should be found begging or vagrant, he should be taken before a magistrate, who might direct him to be whipped out of the place at the end of a cart, "till his body was bloody," and should then be sworn to return to the place where he was born, or last dwelt by the space of three years, and there to put himself to labour as a true man ought to do. He was to be provided with a certificate of his punishment, stating the place to which he was going and the time allotted for his journey; and during that time he might beg by the way. Another law passed against beggars and vagabonds was the 27 Hen. VIII., c. 25, which, though severe in its terms against such persons, approached more nearly to just principles than previous enactments on the same subject, inasmuch as it provided a legal mode of supporting the poor, and thus took away the common apology for vagrancy. This law directed the governors of shires, cities, towns, hamlets, and parishes, to find and keep every aged, poor, and impotent person, by way of voluntary and charitable alms, with such convenient alms, that none of them should be compelled to go openly in begging: children under fourteen years of age and above five, taken begging, were to be put to work: "a valiant beggar or sturdy vagabond" was to be, for the first offence, whipped and sent to his place of settlement; and if he continued his roguish life, to have the upper part of the gristle of his right ear cut off; and if after that he was taken wandering in idleness, or did not apply to his labour, or was not in service with any master, he was to be indicted and tried as a felon, and if found guilty, to suffer death.

Notwithstanding the above laws, vagrancy appears to have greatly increased at the commencement of the reign of Edward VI., of which effect the abolition of monasteries was one main cause. Previously to the Reformation churches were bound by law, both civil (stat. 15 Rich. II., c. 6) and ecclesiastical, to contribute a portion of their income to the living and sustenance of the poor, and the gates of the religious houses were thronged by beggars, who daily received a donation of food, and sometimes of money. This practice contributed no doubt to increase the number of idle beggars, who, upon the withdrawal of their accustomed means of support by the dissolution of the monasteries, became vagrants. To remove the pressure of the evil thus occasioned, an enactment of unexampled severity was devised. The stat. 1 & 2 Edw. VI., c. 3, after reciting that "the multitude of people given to vagabondrie and idleness had always been within this realm very great, and more in number than in other regions," and that the laws of preceding reigns had been found ineffectual, repealed all statutes previously made for the punishment of vagabonds and sturdy beggars. It then enacted that all able-bodied persons, without property sufficient for their support, who should, "either like serving men wanting masters, or like beggars, or after any other such sort, be lurking in any house, or loitering or idle-wandering by the highway's side," or who in towns should not apply themselves to any service or art, and should so continue for three days without offering to labour for meat and drink (if no man otherwise will take them); or who, having been taken to service, should leave their work or run away, should be taken to be vagabonds; and that it should be lawful for any person having offered or given work to any such idle person, and for any other person espying the same, to bring such idle person before two justices, who should immediately cause him to be marked with a hot iron on the breast with the letter v, and adjudge him to such presenter "*to be his slave; to have and to hold the said slave unto him, his executors, or assigns, for the space of two years then next following*, and to order the said slave as followeth (that is to say), to take such slave with him, and only giving him bread and water, or small drink and such refuse of meat as he shall think meet, cause him to work by beating, chaining, or otherwise in such work and labour (how vile soever it be) as he shall put him unto." The statute also provides that an action of trespass may be maintained for a runaway slave, and that the runaway himself shall, upon his apprehension, be adjudged by two justices to be his master's slave for ever. If he ran away a second time, the slave became a felon, and might be tried and executed as such. This singular enactment further declared that a master might "let, set forth, sell, bequeath or give" the service and labour of such slaves, upon such condition and for such term of years as he might do with any other of his moveable goods or chattels. "Some thought," says Burnet, "this law against vagabonds was too severe, and contrary to that common liberty of which the English nation has always been very sensible. Yet it could not be denied but extreme diseases required extreme remedies; and perhaps there is no punishment too severe for persons that are in health, and yet prefer a loitering course of life to an honest employment." ('History of the Reformation,' vol. ii., p. 45.)

The consequence of the absurd severity of this law was that its provisions were not carried into execution; and being found wholly ineffectual, it was repealed by the statute 3 & 4 Edw. VI., c. 16, which also repealed all former laws upon the same subject excepting the 22 Hen. VIII., c. 12. Another statute of the same reign (5 & 6 Edw. VI., c. 2) slightly modified the preceding laws; but the regulation of vagrants and mendicants stood in effect upon the footing of the three last-mentioned statutes until the latter part of the reign of Elizabeth.

About the beginning of the reign of Elizabeth, a description of persons called *rogues* first appeared in the general class of vagrants. The derivation of this word is variously given by etymologists. Horne Tooke derives it from a Saxon word signifying "cloaked," or covered. ('Diversions of Purley,' vol. ii.) Webster takes it from another Saxon word, and Dr. Johnson admits its derivation to be uncertain. Lambard says "the word is but a late guest in our law; for the ancient statutes call such a one a valiant, strong, or sturdy beggar, or vagabond, and it seemeth to be fetched from the Latin 'rogator,' an asker or beggar." ('Eirenarcha,' book iv., chap. 4.) Dalton also says "a rogue may be so called quia ostiatim rogat." ('Country Justice,' chap. 83.) It is believed that the word does not occur in the English language before the middle of the 16th century; and if so, it is probably one of those numerous cant words by which, at that period, vagrants, in counterfeiting Egyptians or gipsies, began to designate different classes of their own "ungracious rabble," and of which Harrison enumerates twenty-three degrees. (Harrison's 'Description of England,' prefixed to Holinshed's 'Chronicles.')

In the course of the reign of Elizabeth the evils of vagrancy increased to an alarming extent; and although the accounts given by historians of the multitude of vagabonds in England are founded upon rude estimates, and are probably somewhat exaggerated, there is undoubted evidence that the numbers and attitude of these persons at that period constituted an evil of dangerous magnitude. Strype relates that in 1569 circular letters were issued by the privy council to the sheriffs of the different counties, directing them to search for and apprehend "all vagabonds and sturdy beggars, *commonly called rogues or Egyptians*;" and he says that on the search through the nation 13,000 "masterless men" were taken up. (Strype's 'Annals,' vol. i., part 2, pp. 295, 296, 554.) Harrison, who wrote towards the end of Elizabeth's reign, states that the number of vagrants in England in his time amounted to above 10,000 ('Description of England'); and Strype publishes a paper, written, in 1596, by a justice of the peace of Somersetshire, which affirms that there were 300 or 400 wandering idle people in every county, who met at fairs and markets for purposes of theft and rapine, and who sometimes assembled in troops to the number of 60, and completely overawed the magistrates and constables by their audacious threats. (Strype's 'Annals,' vol. iv., p. 405.) The recorder of London, in a letter to Lord Burleigh, written in 1581 (Ellis's 'Letters,' vol. ii., p. 283), gives a remarkable account of the prevalence of vagrants in the metropolis at that period. He says, that being informed that the queen, "in taking of the air in her coach at Islington, had been environed with rogues," he went abroad himself and took seventy-four rogues, "whereof some were blind, and yet great usurers and very rich." A day or two afterwards he says that, in consequence of warrants issued by him, he received "a shoal of forty rogues, men and women, from Southwark, Lambeth, and Newington," and after bestowing them in Bridewell, he "perused" St. Paul's, and took about twenty "cloaked rogues that there used to keep standing." Notwithstanding this zeal and activity, vagrants still increased in the metropolis, both in numbers and audacity; and the efforts of the ordinary magistrates having failed to prevent the frequent and dangerous disorders and tumults occasioned by offenders of this description, they were, in 1595, placed under martial law. The instrument appointing a provost-marshal for this purpose authorises that officer "to repair with a convenient company to all common highways near to the city of London, where he should understand that any vagrant persons did haunt; and calling to his assistance some convenient number of justices and constables, to apprehend all such vagrant and suspected persons, and deliver them to the said justices, to be by them committed and examined of the causes of their wandering." It then directs him that "if such persons should be found notoriously culpable in the unlawful manner of life, as incorrigible, and should be so certified to him by the justices, he should by law-martial cause some of them to be executed upon the gallows or gibbet." (Rymer's 'Fœdera,' vol. xvi., p. 279.)

The means of suppressing or diminishing vagrancy and mendicancy were constant subjects of discussion in the parliaments of Elizabeth. With this view, extraordinary means of relief were devised. Voluntary subscriptions of sums of money, varying in amount according to the rank and supposed ability of the contributors, were made in both

Houses to relieve "the great number of poor people pressing in the streets to beg." (D'Ewes's 'Journals,' pp. 462, 463, 499, 503.) Orders were also made that those who preferred private bills in the House of Commons should pay 10*l.* or 5*l.*, according to the subjects of their bills, to the relief of the poor, to be distributed as the House should appoint. (D'Ewes's 'Journals,' p. 665.) Several statutes were also passed, at one time increasing the punishment for vagrancy, and then repealing it, without any settled principle of legislation. In some of these statutes, however, the notion of a parochial fund for the relief of the poor, and the principle of taxing the parishioners for that purpose, are distinctly recognised. (Stat. 5 Eliz., c. 3; 14 Eliz., c. 5; and 18 Eliz., c. 3.) At length, in 1597, after experience had shown that temporary expedients and ill-directed charity only increased the amount of vagrancy, and that severe punishments and penalties were wholly ineffectual in preventing it, the House of Commons appointed a committee to whom most of the existing laws relating to the condition of the poor, as well as certain bills for their amendment, were referred. (D'Ewes's 'Journals,' p. 561.) This committee, of which Sir Francis Bacon was member, and which was composed of all the practical men of the House, seems to have perceived and to a certain extent acted upon the principle that, in order to justify severity against vagrancy and mendicity, it was necessary to provide the means of relieving that destitution which was the ready and plausible excuse for both. They therefore prepared the stat. 39 Eliz., c. 3, which for the first time organised that machinery for the legal relief of the poor which was a few years afterwards completed and made perpetual by the stat. 43 Eliz., c. 2. The same committee also recommended measures for encouraging the building of "hospitals, or abiding and working houses," for the poor, and for improving and reforming such as were already in existence, but had been misapplied or abused. And at the same time they introduced a more rational enactment for the correction and suppression of fraudulent vagrancy than had previously existed. (Stat. 39 Eliz., c. 4.) "Many statutes," says Sir Edward Coke (2 'Inst.' 728), "have been made for the punishment of rogues, vagabonds, and sturdy beggars, but very few to find them work and to enforce them thereunto." The statute 39 Eliz., c. 4, supplied this deficiency by providing houses of correction, with stocks, and materials for the employment of the inmates, and by enforcing the use of the means thus placed in the hands of the poor by severe penalties against the idle. The provisions of this statute, with some alterations made by the stat. 1 Jac. I., c. 25, continued in force during the whole of the 17th century; and when repealed by the stat. 12 Ann., stat. 2, c. 23, still served as the model and foundation for future acts. It declared that the following persons should be deemed rogues, vagabonds, and sturdy beggars:—1, persons calling themselves scholars going about begging; 2, sea-faring men, pretending losses of their ships or goods, going about begging; 3, idle persons going about the country, either begging or using any subtle craft or unlawful games or plays, or feigning themselves to have knowledge in physiognomy, palmistry, or telling fortunes; 4, persons that were or uttered themselves to be procurers or collectors for jails or hospitals; 5, fencers, bear-wards, common players of interludes and minstrels wandering abroad, other than players of interludes belonging to any baron of the realm, or any other honourable personage of greater degree [THEATRE]; 6, jugglers, tinkers, pedlars, and petty chapmen, wandering abroad; 7, wandering persons and common labourers, able in body, using loitering, and refusing to work for reasonable wages, and having no other means of maintenance; 8, persons delivered out of jail who begged for their fees, or otherwise travelled begging; 9, persons who wandered abroad begging, pretending losses by fire, or otherwise; 10, persons, not being felons (*i.e.*, by a late statute, 5 Eliz., c. 20), wandering and pretending themselves to be Egyptians. A person who committed any of the above offences might, by the appointment of any justice, constable, headborough, or tything-man (the headborough or tything-man being assisted therein by the advice of the minister and another of the parish), be openly whipped till he was bloody, and then sent from parish to parish till he came to the parish where he was born: if that was unknown, to the parish where he last lived for a year; and if that again was unknown, to the parish where he last passed without punishment. He was provided with a testimonial of his punishment, and of the place whereunto he was to go, stating the time limited for that purpose; and if he was found loitering by the way, he might again be whipped. If any rogue appeared to be dangerous to the inferior sort of people, or not likely to be reformed (an expression which seems to have led to the phrase "incorrigible rogues"), two justices might commit him to jail till the next quarter-sessions, and then he might by the justices there be either banished out of the realm, or adjudged perpetually to the galleys of the realm; and any banished rogue returning without leave became a felon.

The several judicious measures which were enacted at this period for the relief and employment of the deserving poor, and the punishment of idle and profligate beggars and vagrants, effectually checked for a time the evil, which had only increased in magnitude under the previous inefficient and inconsistent laws. Sir Edward Coke, whose testimony as a contemporary is valuable, says, that "upon the making of the statute of 39 Elizabeth, and a good space after, whilst justices of peace and other officers were diligent and industrious there was not a rogue to be seen in any part of England; but when justices and other officers became *tepidi* or *trepidi*, rogues, &c. swarmed again." (2 'Inst.' 729.) This disposition on the part of magistrates to neglect or relax the laws relating to vagrants is noticed in a proclamation made soon after the accession of James I., in September, 1603, which, after reciting the stat. 39 Eliz. c. 4, and that great benefit had at first ensued from its due execution, but that, by the remissness, negligence, and connivancy of justices, vagrants again swarmed and abounded everywhere more frequently than in times past, calls upon all justices of peace, mayors, and other officers whatsoever, to see that the said "profitable and necessary law" should be carefully, duly, and exactly executed (Rymer's 'Fœd.,' vol. xvi., p. 554). The continued unwillingness of magistrates to enforce the statute of Elizabeth, notwithstanding the above proclamation, occasioned the passing of the stat. 7 Jac. I .c. 5, which compelled the justices of every county under heavy penalties to erect proper houses of correction for setting rogues, vagabonds, and other idle and wandering persons to work, and also required them to meet twice a year or oftener, if occasion required, for the better execution of the law. The justices were also directed to cause a general privy search to be made before each of their meetings for finding out and apprehending vagrants, who were then to be brought before them for punishment; and all constables and tythingmen were required to make a return on oath to the justices of the number of vagrants apprehended by them. By this statute it was also enacted that persons running away and leaving their families upon the parish should "be deemed and taken to be incorrigible rogues, and endure the pain of incorrigible rogues." This phrase was, therefore, at that time become familiar, though it does not occur in any earlier statute. In all probability, however, it denoted the class of persons mentioned in the stat. 39 Eliz. c. 4, who are there called "dangerous rogues, or rogues not likely to be reformed," and who were liable to be committed to jail until the sessions, and then banished.

The laws relating to vagrants continued substantially upon the footing of the statutes of 39 Eliz. and 7 Jac. I. for more than a century, until, in 1744, they were reconsidered and remodelled by the stat. 17 Geo. II., c. 5. This was the first legislative measure which distributed vagrants into the three classes of idle and disorderly persons, rogues and vagabonds, and incorrigible rogues. Although this statute is now wholly repealed, it continued in force nearly a century; and as its provisions, as well as those of two supplemental statutes on the same subject, are material with respect to the general history of the laws respecting vagrants, it may be desirable briefly to state them. It may be remarked that the several offences comprised in these classes still bore the character of wandering, in conformity with the object of all previous enactments upon this subject.

By the stat. 17 Geo. II., c. 5, and the supplemental statutes passed previously to the new Vagrant Act, 5 Geo. IV., c. 83, idle and disorderly persons were defined to be—1. Those who threatened to run away and leave their families upon the parish. 2. Those who returned to a parish from which they had been removed as paupers. 3. Those who refused to work for usual wages. 4. Those who neglected work or spent their earnings improperly, so that their families became chargeable to the parish (stat. 32 Geo. III., c. 45, s. 8). And all such persons might be summarily convicted by a magistrate, and committed to hard labour in the house of correction for a month.

Rogues and *vagabonds* were defined to be—1. Those who went about as gatherers of alms under pretence of loss by fire or other casualty, or as collectors for prisons or hospitals. 2. Fencers and bear-wards. 3. Common players of interludes, and all actors for hire not authorised by law [THEATRE]. 4. Minstrels and jugglers. 5. Those who pretended to be gipsies, or to have skill in physiognomy, palmistry, or like crafty science, or to tell fortunes, or who used any subtle craft to deceive people, or played at unlawful games. 6. Those who ran away and left their families chargeable to the parish. 7. Petty chapmen and pedlars wandering abroad without licence. 8. Those who wandered abroad and lodged in alehouses, barns, outhouses, or in the open air, not giving a good account of themselves. 9. Those who wandered abroad and begged, pretending to be soldiers or sailors, or pretending to go to work in harvest. 10. All wandering beggars. 11. Those who should be apprehended having upon them any picklock key, crow, jack, bit, or other implement with intent to break into houses, &c.; or any pistol, hanger, cutlass, bludgeon, or other offensive weapon, with intent feloniously to assault any person. 12. Those who should be found in any dwelling-house, warehouse, coach-house, stable, or outhouse, or any inclosed yard or garden, or area belonging to any house with intent to steal. The two classes last enumerated were added by the stat. 23 Geo. III., c. 88.

Incorrigible rogues were defined by the stat. 17 Geo. II., c. 5, to be—1. End-gatherers offending against the stat. 13 Geo. I., c. 23, for the regulation of the woollen manufacture. 2. Those who being apprehended as rogues and vagabonds escape from those who apprehend them, or refuse to go before a magistrate, or to be examined on oath, or to be conveyed by a pass, and those who knowingly give a false account of themselves. 3. Those who escape from the house of correction before the expiration of their term of imprisonment as rogues and vagabonds. 4. Those who after punishment as rogues and vagabonds again commit offences in the same class.

Rogues and vagabonds and incorrigible rogues were, by the stat. 17 Geo. II., c. 5, to be committed by magistrates to the house of correction until the next quarter-sessions, when the justices were empowered to order rogues and vagabonds to be further confined in the house of correction for any time not exceeding six months; and incorrigible rogues for any time not less than six months, nor more than two years, and to be whipped.

The statute 17 Geo. II., c. 5, was by no means a well-considered or a well-expressed law. It has been justly said that "in the long catalogue of actions which it holds up, many are of a dubious nature, and nice legal acumen would often be required to distinguish whether a person had incurred any and what penalty under the statute." (Eden's 'State of the Poor,' vol. i., p. 306.) The courts too complained of the inaccuracy of its expression and the consequent difficulty of understanding its meaning. (Rex *v.* Rhodes, 4 'Term Reports,' 222.) Repeated attempts were made in parliament to modify and improve its provisions. A committee of the House of Commons, appointed in 1775 to review and consider the Poor Laws and the laws relating to vagrants, resolved "that the stat. 17 Geo. II., c. 17, should be explained and amended in such a manner as to enforce the execution thereof, and prevent the practice of begging in the streets and highways, pernicious in its consequences and highly disgraceful to this country." Nevertheless this statute continued in force until the year 1822, when a temporary act, stat. 3 Geo. IV., c. 40, passed, repealing all former laws and re-enacting most of the provisions of the stat. 17 Geo. II., c. 5, with many additions and modifications. The provisions of the stat. 3 Geo. IV., c. 40, were however entirely superseded by the stat. 5 Geo. IV., c. 83, which now constitutes the law respecting vagrants. By the third section of this statute the following persons are declared to be *idle* and *disorderly* persons, and may be committed by a single magistrate to hard labour in the house of correction for any time not exceeding one month:—1. Every person able to maintain himself and his family, refusing or neglecting to do so, whereby he or his family become chargeable to the parish; 2. Every person returning and becoming chargeable to a parish from which he has been legally removed by order of two justices without having a certificate of his settlement in some other parish from the officers of such parish; 3. Petty chapmen or pedlars wandering abroad and trading without licence; 4. Prostitutes wandering in the streets or highways, or in any place of public resort, and behaving riotously or indecently; 5. Every person wandering abroad or placing himself in any public place to beg and gather alms, or procuring any child to do so. To which other statutes have since added:—6. Paupers in workhouses, not doing task-work when required, or injuring their clothes or damaging the property of the guardians; 7. Women neglecting to maintain their illegitimate children; and, 8. Persons applying for relief as paupers, having possession of money, &c., of which they do not make disclosure. These offenders are punishable by a single justice with one month's imprisonment and hard labour.

The 4th section of the 5 Geo. IV., c. 83, declares the following persons to be *rogues* and *vagabonds*, and empowers a single magistrate to commit them to hard labour in the house of correction, for any time not exceeding three months:—1. Every person committing any offence which would constitute him an idle and disorderly person; 2. Every person pretending to tell fortunes, or using any device, by palmistry or otherwise, to deceive and impose upon the people; 3. Every person wandering abroad and lodging in any barn or outhouse, or in any deserted building, or in the open air, or under a tent, or in any cart or waggon, not having any visible means of subsistence, and not giving a good account of himself; 4. Every person wilfully exposing to view in any street, road, highway, or public place, any obscene print, picture, or other indecent exhibition. (By 1 & 2 Vict., c. 38, this provision is declared to extend to exposing such articles in a shop window.) 5. Every person wilfully and obscenely exposing his person in any street or highway, or in the view thereof, with intent to insult any female; 6. Every person wandering abroad and endeavouring by the exposure of wounds or deformities to gather alms; 7. Every person going about as a gatherer or collector of alms, or endeavouring to procure charitable contributions under a false pretence; 8. Every person running away and leaving his wife actually or probably chargeable to the parish; 9. Every person playing or betting in any street, highway, or public place with any table or instrument of gaming, at any game of chance; 10. Every person having in his possession any picklock-key, crow, jack, bit, or other implement, with intent feloniously to break into any house, &c., or being armed with any gun, pistol, hanger, cutlass, bludgeon, or other offensive weapon, or having upon him any instrument with intent to commit any felonious act; 11. Every person, being found in any dwelling-house, warehouse, coach-house, stable or outhouse, or in any inclosed yard, garden, or area for any unlawful purpose; 12. Every suspected person or reputed thief frequenting any river, canal, or navigable stream, dock, basin, or any quay, wharf, or warehouse near or adjoining thereto, or any street, highway, or avenue leading thereto, or any place of public resort, or any avenue leading thereto, or any street, highway, or place adjacent, with intent to commit felony; 13. Every person apprehended as an idle and disorderly person, and violently resisting any peace-officer so apprehending him, and being subsequently convicted of the offence for which he shall have been so apprehended.

Incorrigible rogues are—1. Persons breaking or escaping out of any place of legal confinement before the expiration of the term for which they shall have been committed, or ordered to be confined by virtue of the statute; 2. Persons committing any offence against the statute which subjects them to be dealt with as rogues and vagabonds, such persons having been at some former time adjudged so to be and duly convicted thereof; and, 3. Every person apprehended as a rogue and vagabond, and violently resisting any constable or other peace-officer so apprehending him, and being subsequently convicted of the offence for which he shall have been so apprehended. These offenders are to be committed to the next sessions, and kept to hard labour in the interim; and the sessions may further punish them by imprisonment with hard labour for one year, and if males, with whipping.

The statute, besides the definition of the facts and circumstances which are to constitute offences in the several classes above enumerated, contains various provisions for the prosecution of vagrants and the regulation and disposal of them. Thus it is enacted that any person may apprehend a vagrant and bring him before a magistrate. The persons as well as the carriages or luggage of the several descriptions of vagrants may be searched, and money or goods found upon them may on their conviction be applied towards the costs of apprehending them and maintaining them in prison. If proceedings at the sessions are contemplated, either by reason of an appeal against a *summary* conviction or the commitment of an incorrigible rogue, the committing magistrate may bind over witnesses to prosecute, and the justices at sessions may order the payment of costs to persons so bound. And an appeal is given to the next sessions to any person aggrieved by an act or determination of any magistrate out of sessions concerning the execution of the act.

(See Blackstone's *Commentaries*, by Kerr, vol. iv.)

VALERACETONITRILE. [Valerianic Group.]

VALERAL. [Valerianic Group.]

VALERALDEHYDE. [Valerianic Group.]

VALERALDINE. [Valerianic Group.]

VALERAMIDE. [Valerianic Group.]

VALERANILIDE. [Valerianic Group.]

VALERENE. [Valerianic Group.]

VALERIA'NA OFFICINALIS—*Medical Properties of.* The root, or more properly the rhizoma with its root-fibres, of this species, particularly the variety termed *sylvestris*, is used in medicine. It should be collected in spring before it shows flower, or late in autumn. It is best from plants of two or three years old, which grow in elevated stony places, rather than in very moist meadows. It varies considerably in appearance and in its sensible properties, according to the age of the plant, its place of growth, and the length of time it has been kept. The rhizoma is small, short, rounded or oblong, truncated, furnished with very many root-fibres, which are about the thickness of a straw, and from two to six inches long; the colour of the freshly obtained root is a dirty yellowish-white; the consistence fleshy; by drying, which is easily effected, it becomes wrinkled, more yellow or brownish, and in time dark. The root gathered in spring becomes most wrinkled. The odour is heavy, penetrating, and very characteristic. This odour is stronger in the dried than the fresh root, and is scarcely impaired by time, even when the access of the air is freely allowed. The taste is acridly aromatic, camphoraceous, and bitter. The English Valerian is the most esteemed: it is abundant in Hampshire, formerly in Kent and Essex, and the wild plant is to be preferred to that which is cultivated for medical use. It is to be regretted that this root is often confounded or fraudulently adulterated with that of the *Valeriana dioica*, which is smaller and of much feebler odour, and that of the *Geum urbanum* or *avens*, which is pleasantly aromatic. Much more serious is the confusion, probably always accidental or merely from ignorance, of the genuine root with those of several species of ranunculus, or crowfoot, namely, *R. repens*, *acris*, and even *polyanthemos*, also those of *Sium angustifolium* and *S. latifolium*, or more rarely *Helleborus niger* and *Asclepias Vincetoxicum*; but the absence of the peculiar odour of valerian, or the presence of a very repulsive one, may always distinguish them with moderate attention.

According to the analysis of Trommsdorf ('Journal der Pharmacie,' xviii., p. 8), 100 parts of the dried root yield of volatile oil 1·2, peculiar resinous extractive (termed valerianin) 12·5, gummy extractive 9·4, soft resin 6·2, woody fibre 70·7; by distillation a volatile fatty acid termed valerianic acid is obtained, besides the volatile oil. The medicinal action is chiefly due to the volatile oil and extractive. Valerian is considered a *cerebro-spinal* stimulant, large doses of it causing marked excitement of the nervous system, not only of the human race, but also of cats, which are remarkably fond of it. In the slighter forms of nervous diseases not dependent on any change of structure of the brain or spinal cord, valerian is of considerable utility. In several instances, especially if there be much acidity of stomach, its beneficial effects are increased by combination with ammonia. In other instances valerian (in powder) greatly heightens the tonic power of the *disulphate of quinia*, the absence of all aroma from which renders it inferior as a tonic to many of the other forms of administering bark. [Cinchona.]

Valerianic acid, combined with various bases, such as iron, zinc, quinine, &c., furnishes compounds of great value as antispasmodics—more useful than any of these agents singly.

VALERIANIC ACID ($HO,C_{10}H_9O_3$). *Valeric acid. Delphinic acid. Phocenic acid.* This body exists in valerian root, hence its name; in the oil secreted by several species of phoca (hence *phocenic*) and cetacea, and in the berries of the guelder rose. It is also a product of the action of caustic potash on oil of camomile; of oxidising agents on fats; is often present in decaying cheese; and is formed on passing amylic alcohol (fousel or fusel oil) vapour through a tube containing the hydrates of soda and lime heated to 400 Fahr. In the latter process valerianate of soda is produced, which, when cool, must be plunged rapidly into cold water, or it would take fire spontaneously. The aqueous solution acidified with sulphuric acid and distilled furnishes valerianic acid. Another and more convenient method is to distil a mixture of amylic alcohol, bichromate of potash, and sulphuric acid:—

$$\underbrace{C_{10}H_{11}O,\ HO}_{\text{Amylic alcohol.}} + O_4 = 2HO + \underbrace{HO,\ C_{10}H_9O_3}_{\text{Valerianic acid.}}$$

Some valerianate of amyl also passes over; the distillate should therefore be heated with caustic potash when amylic alcohol is volatilised: the residual valerianate of potash may then be decomposed by sulphuric acid and the mixture distilled, when pure valerianic acid will be obtained.

Valerianic acid forms two hydrates. When it is separated from the aqueous solution of a valerianate by a stronger acid, it contains, according to Liebig, three atoms of water, of which two may be separated, by distillation, in the state of pure water, which afterwards becomes milky, and at last the colourless monohydrate passes over in distillation.

This monohydrate is oleaginous, very fluid, of an acid penetrating odour, like the valerian root; its taste is acrid and sharp, with a sweetish after-taste; it produces a white spot on the tongue. It does not become solid at 0° Fahr. Its density is 0·937, and it boils at 347° Fahr. The terhydrate boils at about 270°. The monohydrate dissolves in 30 parts of water at 53°: it dissolves in all proportions in alcohol, ether, and crystallisable acetic acid; sulphuric acid when heated carbonises it. It dissolves iodine and camphor.

Valerianic acid combines with bases to form salts, which are called *valerianates;* the potash and soda salts are very soluble, deliquescent, and crystallise with difficulty. The valerianates of lime and baryta are also very soluble, but they are crystallisable and unalterable in the air; the magnesian salt crystallises in efflorescent needles. The pure monohydrate absorbs much ammonia, becoming, after a time, a solid mass of snow-white, non-deliquescent, crystals of valerianate of ammonia. Valerianate of zinc, readily prepared by double decomposition and used to some extent in medicine, is a pearly white salt, having a faint odour of valerianic acid and a metallic astringent taste.

Chlorovalerisic Acid ($HO,C_{10}(H_6Cl_3)O_3$) and *chlorovalerosic acid* ($HO,C_{10}(H_5Cl_4)O_3$) are formed when chlorine gas is passed into valerianic acid. They are heavy colourless, inodorous liquids, and form well-defined, stable monobasic salts. From the amount of chlorine in them, these acids are sometimes termed *trichlorovalerianic* and *tetrachlorovalerianic acid.*

Nitrovalerianic Acid ($HO,C_{10}(H_8NO_4)O_3$) is a volatile, beautifully-crystalline body, resulting from the prolonged action of the strongest boiling nitric acid on valerianic acid. It is sublimable and forms stable salts.

Valerianic anhydride or *anhydrous valerianic acid* ($(C_{10}H_9O_3)_2$) is formed when one part of oxychloride of phosphorus is gradually added to six parts of dry valerianate of potash; the product is washed with dilute solution of carbonate of soda, digested in ether, the etherial solution dried with chloride of calcium and evaporated, when valerianic anhydride is left as a colourless liquid of agreeable odour; sp. gr. 0·934; boiling point, 419° Fahr.; vapour density, 6·23.

VALERIANIC GROUP. A cluster of chemical substances, each supposed to contain, or be derived from, the theoretical radical *valeryl* ($C_{10}H_9O_2$).

Valerianic acid is best produced by the action of strong oxidising agents on fusel oil. [Valerianic Acid.]

Valeryl-aldehyd or *valeral* ($C_{10}H_9O_2$, H), *hydride of valeryl,* is formed on oxidising fusel oil (amylic alcohol) with less powerful agents than those necessary to form valerianic acid. Thus a mixture of bichromate of potash, sulphuric acid, and fusel oil furnishes valeral. It is purified by mixing with a saturated solution of bisulphite of soda, recrystallising the double salt thus formed, distilling with carbonate of potash, and drying the distillate over chloride of calcium. Valeral is a colourless limpid liquid of powerful penetrating odour, and burning taste; soluble in alcohol, ether, and the volatile oils; insoluble in water; burns with a bright flame; boils at 230° Fahr.; vapour density, 2·96; specific gravity, at 71° Fahr., is 0·820; oxidising agents convert it into valerianic acid, and ammonia combines with it to form crystalline *valeryl-aldehyd-ammonium* or *valerylide of ammonium* ($C_{10}H_9O_2$, NH_4).

Valeraldine ($C_{30}H_{31}NS_4$) results from the action of sulphide of hydrogen on valeryl-ammonium suspended in water containing a small quantity of free ammonia:—

$$3(C_{10}H_9O_2,\ NH_4) + 6HS = C_{30}H_{31}NS_4 + 6HO + 2NH_4S$$

It is an oily, volatile, alkaline liquid of disagreeable odour, and combines with acids to form salts.

Leucin, a body associated with the chemistry of animal substances, appears to be a valeryl derivative, inasmuch as it may be formed by the action of hydrocyanic and hydrochloric acids upon valerylide of ammonium. It is treated of in detail in a separate article. [Leucin.]

Chloride of valeryl ($C_{10}H_9O_2$, Cl) is formed on reacting with protochloride of phosphorus and monohydrated valerianic acid. It is a colourless mobile, fuming, liquid; rather heavier than water, and boils at about 240° Fahr.

Bromide of valeryl ($C_{10}H_9O_2$ Br), is obtained in the same manner as the chloride, the bromide instead of the chloride of phosphorus being used. It boils at about 290° Fahr.

Valerone ($C_{18}H_{18}O_2$), the *valerylide of butyl* (C_8H_9, $C_{10}H_9O_2$), is a light colourless liquid of agreeable ethereal odour, produced when valerianic acid is distilled with excess of lime. A mixture of valerate of potash and acetate of soda yields, by distillation, an oil which is probably *valerylide of methyl* (C_2H_3, $C_{10}H_9O_2$).

Valeramide $\left(N \left\{ \begin{matrix} C_{10}H_9O_2 \\ H \\ H \end{matrix} \right.\right)$ is formed by boiling valerianic ether (valerate of ethyl) with strong ammonia: on concentrating and cooling the solution, valeramide crystallises out in brilliant plates. It is neutral, fusible, volatile, and soluble in water, alcohol, or ether. Heated with phosphoric anhydride it loses the elements of water and is converted into *cyanide of butyl* (C_8H_9, NC_2) or *valeronitrile* ($C_{10}H_9$, N).

Valeronitrile is also one of the products of the oxidation of gelatin by chromic acid; it is accompanied by another somewhat similar liquid *valeracetonitrile* ($C_{26}H_{21}N_2O_6$). *Valeranilide* or *phenyl-valeramide* $\left(N \left\{ \begin{matrix} C_{10}H_9O_2 \\ C_{12}H_5 \\ H \end{matrix} \right.\right)$ is produced on digesting valerianic anhydride and aniline together. It crystallises in long, brilliant needles, slightly soluble in water, but very soluble in alcohol; melts at 239° Fahr., and boils without decomposition at 428° Fahr.

Valerins. Combinations of valerianic acid and glycerin. Three of these have been obtained, namely:—

Monovalerin . . $C_{16}H_{16}O_8 = C_{10}H_{10}O_4 + C_6H_8O_6 - 2HO$
Divalerin . . . $C_{26}H_{24}O_{10} = 2C_{10}H_{10}O_4 + C_6H_8O_6 - 4HO$
Trivalerin . . $C_{36}H_{32}O_{12} = 3C_{10}H_{10}O_4 + C_6H_8O_6 - 6HO$

The proportion of the constituents, the temperature employed and the state of concentration of the mixture, determines which of the three shall be formed. *Valerochlorhydrin* is a valerin containing the elements of hydrochloric acid.

Valeryl-urea or *valerureide* has already been alluded to [Urea].

Oil of valerian, obtained as described under ESSENTIAL OILS, generally contains about 5 per cent. of valerianic acid; 25 per cent. of a neutral volatile hydrocarbon, boiling at 160° Fahr., and termed *valerene* ($C_{20}H_{16}$), identical with the borneene of Borneo camphor; and about 70 per cent. of an oxidised portion containing resin and valerol. *Valerol* ($C_{24}H_{20}O_2$) is a stearopten, and condenses as a crystalline solid in the neck of the retort in which the oil of valerian is fractionated. It is lighter than water, in which it is insoluble; is readily dissolved by alcohol, ether, and essential oils; is resinified slowly in the air, more readily by nitric acid; and with sulphuric acid forms blood-red *sulphovalerolic acid.*

VALERIC ACID. [Valerianic Acid.]

VALERIC ETHER. [Ethyl.]

VALERINE. [Valerianic Group.]

VALEROCHLORHYDRIN. [Valerianic Group.]

VALEROLE. [Valerianic Group.]

VALERONE. [Valerianic Group.]

VALERONITRILE. [Valerianic Group.]

VALERUREIDE. [Urea; Valerianic Group.]

VALERYL. [Valerianic Group.]

VALERYLUREA. [Urea; Valerianic Group.]

VALLEYS. The term Valley, from the Latin *Vallis* or *Valles,* of the same signification generally, may be applied, in its most comprehensive meaning, to any depression on the surface of the globe. "The largest valleys form the beds of the great oceans. Seas, bays, gulfs, &c., are all valleys below, or partially below, the level of the sea." But in the common acceptation of the term, valleys are those depressions which are observable above the sea-level, separating or intersecting mountain-ridges, and in fact breaking them up into separate mountain-masses, and in which are the basins of inland seas and lakes, the beds of rivers, &c. Mountains and hills, therefore, are the boundaries of valleys. Occasionally a valley is formed by a ridge of elevated land entirely, or almost entirely, surrounding the basin of an inland sea or of a lake. The word *vale,* sometimes employed synonymously, is the diminutive, but is more properly applied to the depressions between eminences of moderate elevation, or hills, which, together with them, form what is called undulating country. Valleys parallel to the mountain-ridges or chains which they separate, or which bound them, are said to be longitudinal; while those the direction of which is transverse are so called. Both may be principal or lateral, the latter designation being usually applied to the smaller transverse valleys uniting the principal. But these epithets admit of innumerable variations, and merge, in fact, into common descriptive language.

The citation above, in which the term valley is applied to the depressions filled by sea, is from an unquestioned authority, the Rev.

C. G. Nicolay, in the 'Manual of Geographical Science.' But though the sea-basins or ocean-hollows may be included within the necessary geometrical definition of valleys, as being depressions below the average level of the external surface of the solid crust of the globe, and continents and islands within that of mountains, as being elevations above it, we conceive that some distinction in this respect should be established in the nomenclature of geology and physical geography. The surface of the globe above which continents and islands are raised,—that is, the bed of the sea, universally,—cannot be considered as identical, as a geographical or geological element, with the surfaces of those masses of land themselves, on which are the minor, and in this sense secondary, elevations and depressions we commonly call mountains and valleys. Many of the phenomena of configuration and physical state presented by the latter could only have been occasioned by causes connected with the agency of an aërial atmosphere; and while many of them also have had a subaqueous origin, yet the configuration of those parts of continents and islands which are below the level of the sea must have been received from operations exclusively subaqueous. The forms of the proper surface of the land were produced originally by its elevation through the surface of the ocean to a subaërial position above it, and have been completed by atmospheric and fluvial erosion.

Many valleys, for example, were first excavated by marine currents during their elevation, and have been reduced to their present figure by the rivers which have flowed through them from the period of the elevation above the sea-level of the eminences which bound them.

But the forms of the masses constituting continents and islands have been produced by the agency of elevatory and marine forces only, except in the cases of the subsidence of land previously fashioned more or less by atmospheric action. However, the chief differences, probably, between the configurations of the surface of the land and those of the more extended surface consisting of the sea-bed and the land regarded as one, depend on their relative magnitude and on the depth of the sea, which, in fact, is merely the measure of the vertical dimensions of the latter. Around the islands of that part of the Indo-Australian archipelago which is physically a portion of Asia, the sea is so shallow that those islands may truly be regarded as the summits of mountain-masses separated by valleys of very inconsiderable depth, inferior indeed to that of many of the terrestrial valleys upon them. Those islands are in fact united by a vast submarine plain, which abruptly terminates westward near the north-eastern coasts of Borneo, in the middle of the Straits of Macassar, and in the Strait of Lombock, in an unfathomable ocean. We then come to the island-masses of Lombock and the chain immediately to the west, the Moluccas, New Guinea, and the other Australian islands, rising abruptly again from the bottom of this ocean, and thus exemplifying one of the peculiar characters of the masses of land which rise from and bound ocean-hollows; and how characteristic of them is the form thus produced will appear in the sequel. Islands fundamentally volcanic—especially if, like Teneriffe, they contain one principal volcano—are probably altogether conoidal, the submarine portion being merely the continuation of the subaërial. [Volcanos.]

Another difference, originating in the different process of formation, is this: while mountains proper have characteristically smaller dimensions above than below, and thus approximate more or less nearly to the figure of triangular prisms, of pyramids, or cones, their altitude being their principal dimension, the masses of continents and islands are tabular in form, with sides of every degree of obliquity, and sometimes very nearly vertical, their upper surface being much greater in area than their sides, their altitude being their least dimension, and their form thus approximating to that of a low parallelopiped. Valleys proper, again, are widest at the top, and approach in general to the form of an inverted triangular prism, more or less obtuse or acute, or to that of an inverted pyramid, or to the frustum of such a prism or pyramid, the edge or apex being replaced by a plane—the floor of the valley; while the intervals between continents are almost as tabular in form as the masses of the land, but their lower surface, while its area is much greater than that of the sides, being less than the upper formed by and at the level of the sea. [Soundings, Deep Sea.]

The configuration of land above the level of the sea which most nearly resembles the continental masses is that which is called *Table-land*, such as the table-lands of Tibet, Eastern Africa, and Mexico; and the intervals which separate different portions of them most nearly answer to the ocean-hollows between continents. As an example of this may be cited the hollow between the table-land of Tibet on the south, and its recurvature called the Thian-Shan, being a portion of North-Western China, on the north, of which the plain or plateau of Yarkend and Khotan, and what is termed the valley of Lake Lhop, form the base, and which, if we compare the two portions of the table-land to mountains, will answer to a valley, according to the common mode of description. [Plains.] This comparison will hold good, and is illustrative in another respect. Colonel Strachey, in his 'Physical Geography of the Himalayas' (not yet published, but quoted in 'Phil. Trans.,' 1859, pp. 774–776), represents that "the summit of the table-land (of Tibet), though deeply corrugated with mountains and valleys in detail, is in its general relief laid out horizontally." This description will accurately apply to the mass of elevated land which forms a continent or great island, of which it may always be said that while its summit is corrugated with valleys and mountains, it is in its general relief horizontal.

We are led by the previous comparison, and on further investigation, to the apparent fact, that some portions of the earth's surface, however, above the sea-level, present us with the essentially unaltered configuration of other portions which are still below it. From the united geographical researches and inductions of Dr. Thomas Thomson, Dr. Joseph D. Hooker ('Himalayan Journals,' vol. ii., p. 399), and Professor James D. Forbes, it has appeared that the structure of Norway very closely resembles, on a small scale, that of Central Asia, particularly of the Himalaya; and that if it were so elevated that the bottom of the deep fiords which penetrate it became dry land, we should have a model of the Himalaya, with its deep valleys and high acute summits; or, conversely, if the latter country were depressed, so that those valleys became ocean-hollows, the land and mountain-peaks remaining above the sea-level would correspond, on the great scale, to the mountain-peaks of Norway, and the submerged valleys to the fiords. Dr. Thomson ('Western Himalaya and Tibet,' p. 492) has extended this comparison to the structure of Scotland, well known to resemble that of Norway, and to be, in fact, a continuation of it. He has also described (pp. 429–438) the remarkable elevated plain of Karakoram, south of the pass of that name, occupying an immense concavity in the great chain of the Kouen-lun, the northern face of the table-land of Tibet. It measures from six to eight miles in diameter, and has a mean altitude of not less than 17,000 feet, being surrounded by great depressions separating it from the mountains. It has the appearance of having formerly been the bed of a lake, but is itself crossed by several ranges of hills, and by a rivulet, and has a water-parting. This is evidently the configuration of an island in the ocean, agreeing, therefore, with the examples above described.

Conversely, a portion of the bed of the Atlantic, from the coast of Ireland westward, has a configuration resembling that of the land of Western Europe; but still further west, the great Atlantic depression, very unlike a terrestrial valley, commences abruptly, the depth of the sea increasing, within a distance of twenty miles only, from 1320 to 9000 feet, forming a sort of marine cliff on a gigantic scale. For at least a thousand miles the whole surface is one vast depressed plateau, which, according to Professor Ansted (in his 'Geological Gossip,' a work deserving of a more appropriate title), is "totally unlike any equal extent of dry land, though more resembling that on the eastern side of the Andes, in South America, than any other known land." On the (North) American side of the Atlantic plateau "there is a second cliff, facing eastward, having a total rise of about 5000 feet, immediately to the west of which the ground slopes gradually upwards at the rate of about forty feet in a mile, till it reaches the American continent."

We thus arrive at the final confluence of the two branches of the subject. The elevations and depressions of certain parts of the globe, of various magnitudes, closely resemble some of the continental masses and ocean-hollows; while the latter more generally have a distinct and peculiar character; and the corrugations of the upper surface of those masses, ordinarily termed mountains and valleys, in their actual condition, usually differ from both, as already represented. In a paper 'On the Lines of Deepest Water around the British Isles,' by the Rev. R. Everest, F.G.S., read before the Geological Society of London, on June 19th, 1861, and which will probably appear in the 'Quarterly Journal' of that Society, the student will find new materials for pursuing this particular subject.

Some geographical observers, because a river-basin (defined in the article Rivers) is necessarily bounded by high land, except where it declines to the sea, employ the terms "basin" and "valley" of a river indiscriminately and convertibly. Thus, Mr. Alfred R. Wallace begins the chapter of his 'Travels on the Amazon and Rio Negro,' headed "The Physical Geography and Geology of the Amazon Valley," with the statement that "the basin of the Amazon surpasses in dimension that of any other river." Now, although, strictly speaking, the difference between river-valleys and -basins is comparative only, and merges in nature, yet this practice leads to erroneous conceptions of fact; for though a wide valley, through which a river of moderate dimensions having many small tributaries takes its course, may be termed a basin (sometimes called a valley-basin), yet the main stream, as well as its tributaries, must each have its own separate valley, however shallow: such is the Thames, which is described as having a basin, while its valley is often not recognised, though some of its affluents flow through well-characterised valleys. [Thames, in Geog. Div.] On the other hand, the basin of a great river may, and in fact must, include many such wide valleys; and a river-basin, more properly, is the country which is made up of them, and the drainage of which at last finds its way into one stream, and through one principal outlet into the ocean. In this sense, the depression through which the upper course and affluents of the river flow may sometimes be regarded as the basin, while that giving passage to the lower course is properly termed its valley. In the case of the Nile, the depression through which the single stream runs for 1300 miles, from the junction of its last affluent, the Atbara, to the Mediterranean, that is, its lower course, is properly the valley of that river; while its basin comprehends a vast extent of country in Africa, to the eastward, southward, and south-west of that point, made up of many valleys of large dimensions, some giving passage to its great head-streams and tributaries, and almost all to considerable rivers, the affluents of the former respectively.

A form of valley to which the convenient appellation of valley-plain has been given is that which exists when an extensive horizontal surface of land at any elevation, and generally of greater length than width, is surrounded by continuous ranges of mountains rising from and above it. Of this form the so-termed Vale of Tenochtitlan, usually called, after Humboldt, the Valley of Mexico, and the plain, valley, or "Vale" of Cashmere, are examples. The latter is, in fact, the valley of the river Behat or Jelam (by which, however, at least in its present form, it was clearly not excavated), and the inclosed plain, as in many cases of this description, has once been the bed of a lake, and consists, itself, of a lacustrine formation. It depends on the extent of the plain, its degree of unevenness, and the inclination of the slopes, whether or not it shall become and deserve to be called a river-basin.

Another form of valley is the circular spiral, alluded to in the article RIVERS, col. 115. This has been noticed, hitherto, in Eastern Africa only, in the basins and valleys of the eastern affluents of the Nile. Though plainly shown, in one instance at least, in the maps of Abyssinia constructed at the beginning of the 17th century by the Portuguese Jesuit missionaries, Dr. Beke appears to have been the first geographer of modern times to call attention to it, and that from his own explorations. In reference to the Mareb, one of the tributaries of the Atbara, already mentioned, he points out "the remarkable peculiarity which it possesses, in common with many of the rivers of the Abyssinian table-land, of returning on itself, so as to perform a sort of spiral course." The river Abai, or the Nile of Bruce, for example, has a circular spiral course round the peninsula of Gódjam; and while forming this curve, or flowing in a valley of the same figure, it is joined by numerous streams, having their sources in the mountains forming the conoidal core of the peninsula. Dr. Beke has recorded his opinion of the probability that the head-stream of the Nile itself has such a circular spiral course, and therefore flows through a valley of that figure, around a lofty mountain-mass, similar in character to the snow-capped mountains of Samien and Kaffa, in Abyssinia, around which some of the rivers alluded to take their own curved course. This remarkable subject will be noticed again in the geological part of the article. ('Sources of the Nile,' pp. 10, 28; 'Journal of Royal Geographical Society,' vol. xvii., pp. 5, 81.)

In the article RIVERS, col. 113, the Arabian *wadies* have been noticed as the winter-brooks of the countries of which they are characteristic. But this is a figurative use of the term. A *wady*, the correlative of the Hebrew *nachal* (not *nahar*, with which it is confounded in the authorised version of the Scriptures, but which is a river proper), is originally a valley of a peculiar kind. It is a depression, more or less deep or wide or long, worn or washed by the mountain torrents, or winter rains for a few months or weeks in the year. In the article DESERTS, col. 481, the *oases* have been described, after Malte-Brun, as rising in the midst of the sands like islands in the ocean. If we consider the sources of the springs of water which supply them, and to which they owe their existence, to be included in the locality designated an *oasis*, this description is correct. But the oasis itself, like the wady, is properly a species of valley. What the oasis of Ammon, in the western desert of the Nile, "is on a great scale may be seen on a small scale elsewhere; namely, deep depressions of the high table-land, which thus became the receptacles of all the rain and torrents, and, consequently, of the vegetation and the life of the whole of that portion of the desert. These oases, therefore, are to be found wherever the waters from the different wâdys, or hills, whether from winter streams," or from the few living perhaps perennial springs of the country, "converge to a common reservoir." We are indebted for these explicit characters of geographical features much oftener alluded to than understood, to the Rev. A. P. Stanley, who, in his 'Sinai and Palestine,' has so well described the details of the physical geography of those countries.

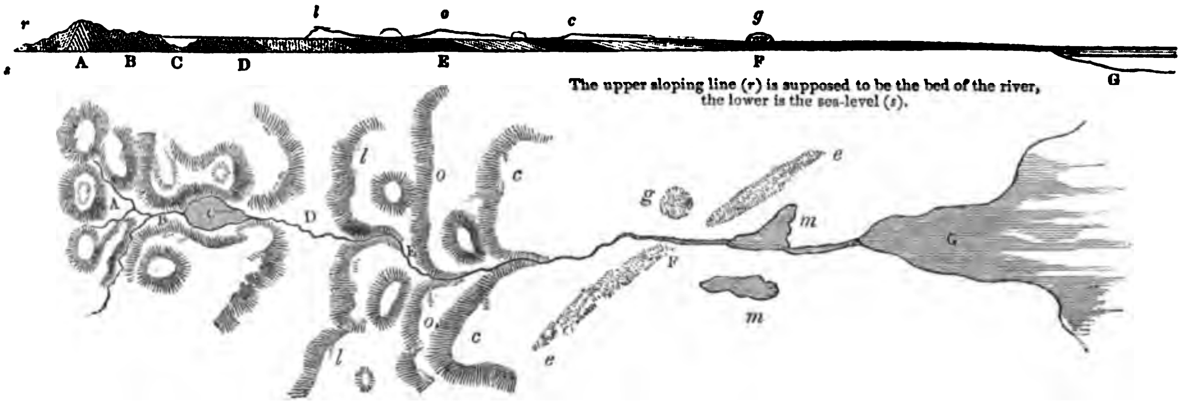
The preceding statements and views relate principally to the subject of valleys geographically considered: their geological history is discussed in the following essay, which originally constituted the article. We have now appended to it some facts and considerations disclosed by and arising from the subsequent progress of geology.

"Why has the earth any mountains?" is the question from which De Luc, writing in 1792, sets out to expound his whole geological system; and to answer at the present time the corresponding question, Why has the earth any Valleys? requires reference to almost the entire series of general truths which have been established by investigation into the structure of the crust of the globe. For in these hollows on the surfaces of plains, hilly slopes, and steep mountains, we behold not only the results of atmospheric agencies, both chemical and mechanical, and of the flowing of streams, operating under the actual conditions of nature on materials of unequal induration, but also the earlier effects of other watery agencies, under other physical conditions, on materials differently circumstanced, both as to their consolidation and their position in reference to the general curve of surface of the globe and the relative level of the sea. The origin of valleys ascends to the earliest geological eras, but their completion includes the latest phenomena produced in our own days.

To discuss the literary history of this celebrated question, and estimate the degrees of truth attained in the conflicting hypotheses of Dr. Hutton and De Luc—which may stand as the types of two great classes of rival speculations, not yet completely reconciled—would be a long, intricate, and unfruitful labour. The problem to be solved has seldom been seized by any but the most modern writers in all its generality; and the partial solutions, really arrived at in particular cases, were not permitted to have even the value which limited truths often do possess, because they were unwisely made the basis of what was called a general theory. Though De Luc could prove that valleys on whose line were deep lakes could not have been excavated by the streams now running in them, he was scarcely entitled to say that "all the notions of the great ravages produced by the rain-waters upon our continents since their existence have been mere illusions." (Letter I. 'On Geology.') And Dr. Hutton might have carried his pupils beyond the mechanical effects of "rivulets that run only in time of rain," before he required them to admit "the great fact, that rivers have in general hollowed out their valleys." (Playfair's 'Illustrations of Huttonian Theory,' Note xvi.)

Theories thus supported were only successful in destroying each other: modern geology has been advanced by a very different process. Mr. Lyell, M. D'Halloy, Mr. Scrope, and other modern writers, have contributed similar partial solutions of particular cases, by careful investigation of the features of the valleys of Auvergne, Belgium, and the Rhenish provinces (see cols. 541–2); but to obtain a general view of the theory of valleys, we must add to these many other equally established local results. This necessity is indeed virtually acknowledged by the eloquent writer to whom the Huttonian hypothesis owes its celebrity, for even while he declares the great hollow of the Valais to be the work of the Rhône, he adds, this tract, when the Alps rose out of the sea, may have included many depressions of the surface which the river joined together, and, from being a series of lakes, became one great valley.

To take the problem of the formation of valleys in all its extent, let us trace in imagination the course of a considerable river, which, commencing in a mountain-ridge, runs to the eastward, namely, in the direction of the dip of the strata, and, after traversing the usual variety of ground, empties itself into a shallow sea full of powerful currents.



The upper sloping line (r) is supposed to be the bed of the river, the lower is the sea-level (s).

A. The summit of drainage between one river area and another being supposed to be below the level of perpetual snows, we find, above the permanent sources of many rivers, occasional feeders, which depend on particular falls of rain, becoming dangerous torrents or appearing as mere lines of pebbles according to the state of the weather. After heavy rains the hill-sides of the highland districts of Scotland, Wales, and Cumberland are whitened by abundance of short-lived torrents, which hurry down considerable heaps of the loosened materials of the hills, and spread them into little deltas on the margin of the valley below. Similar effects on a particular slope follow the bursting of a waterspout (High Pike, in Cumberland) [WATERSPOUT], or the intumescence of a wet peat-bog (above Keighley, Yorkshire). Frost and the sun's heat are felt in extreme in the high regions which give birth to rivers, and by their alternation the rocks are broken and disintegrated. To these regions Hutton and Playfair rightly propose to carry their pupils for the purpose of impressing upon their minds the extensive waste produced on the earth's surface by modern causes in action. Examples are everywhere abundant: Glen Coe, Borrowdale, Snowdonia, may be cited. (N.B. The *general* features of the higher parts of mountain-valleys are nearly the same around glaciers, and these features are liable to change by the violent alternations of temperature.)

B. The second stage of valleys is that which admits of the union of permanent natural springs to the occasional hill-side floods, and of the gathering of these streamlets into a rapid and agitated river. The now augmented water is often confined in a narrower glen than any of its tributaries, and rushes and cascades among rocks and mounds, which are so disposed as to show proof that the course of the stream has varied from time to time, as the levels changed, in consequence of eroding action.

C. At length the glen opens in a pebbly plain, or sinks into a broad and quiet lake. Such lakes, or plains which seem to have been lakes, are of very general occurrence along the line of rivers, while they are engaged in the midst of their parent mountains (Derwent Water, Llanberis, Loch Tay). They even appear at the foot of particular mountains, receiving only occasional streams (Red Tarn, under Helvellyn), and in a very great variety of cases appear to be irregular hollows left after great disturbances of the stratification amongst the angularly posited masses of broken ground. Their depth is from a few feet to a thousand feet (Lake of Geneva) below the level of the valley; and as the rivers which enter the upper ends there lose their force in the expansion of water, and drop their transported sediments, the *growth of new land* in that part of such lakes is proportioned to, and is in truth a measure of, the whole effects of those rivers in transporting away the detritus of the mountains round their source. Such lakes then are *natural dynamometers*, which may with proper caution be used to determine the amount of transported materials delivered into them in given times by rivers; they also give the sum of all the effects of this kind performed by such rivers; and thus finally they are *natural chronometers;* for by dividing, in any particular case, the integral effect or mass of deposited materials by the rate of annual progress, an approximate answer in years is given to the question of the length of time which has elapsed since that river began to flow. By this argument De Luc arrived at the conclusion that the desiccation of our continents by elevation above the sea is a phenomenon of no very great antiquity, belonging to an epoch only a few thousand years removed from our own. Though geologists cannot, from the evidence of particular lakes in certain districts, adopt this conclusion for other districts where quite different phenomena appear, Professor Sedgwick and other eminent persons have declared the argument of De Luc, within its proper limits, to be unanswered and unanswerable. In all cases then where lakes are so interposed in the path of a river that they must be believed to have received all the sediments which that river has brought, the cubic volume of these accumulations in the lake may be compared with the cubic space of the concavities between the hills along the line of the rivers and rivulets above the lake; and if found to be inferior in a noteable degree, we may positively conclude that these concavities have not been produced, though doubtless they have been enlarged and modified, by the atmospheric agencies belonging to that particular area of drainage. Now this comparison has been often made, and generally with the positive result, that the excavation of the valleys above the lakes is not the effect of those watery agencies now exerted within them. Excavated however some of them have been by watery agency, and in all of them the surface slopes have been adjusted by this power, both in level and in direction, to the boundaries of the present lake; but we must avoid the error of assuming that no other currents having a different origin may have operated in those valleys before the existence of the lakes.

D. Beyond the region of the lakes, the rivers, flowing away from the rugged mountains, encounter ranges of stratified rocks, often very regularly inclined at a moderate angle, in parallel ridges and hollows which correspond to alternately hard and soft portions of the series of strata. If there were no gaps across these ridges, so as to connect their intervening hollows, each of these hollows would include one or many lakes, and the river whose course we are tracing could not pass over the first of the ridges until the hollow space between it and the lake district (C) was filled with water, generally at a high level. If such a circumstance were supposed ever to have happened, the waters might be imagined to make themselves a passage across this ridge, and, by like reasoning, across any lower ridges lying beyond. (See the figures above, and in art. GEOLOGY, in NAT. HIST. DIV.)

It sometimes happens that more than one group of such parallel ridges and hollows—as the mountain limestone group (*l*), followed by the oolitic ridges (*o*), or those by the chalk-hills (*c*)—lie on the course of even one river, and require the repetition of such phenomena to account for the course of the valley. But a greater difficulty must be encountered. The very hollows themselves in which these sheets of water are imagined to have spread are valleys, and yield as plain proof that they also have been excavated and modified by watery action, as the river-channels which cross them. For in the midst of such hollows, insulated hills (the unremoved portions of the same or the nearest superjacent strata) remain variously distributed, to mark the ancient height of the land therein, and attest the enormous degradation which has been there occasioned. If, then, the supposed lake gave the force to break over and cut through the inclosing barrier of rock beyond, so as to shape a course and descent to the river, the excavation of the space in which the lake was gathered was the fruit of earlier and different watery action. This conclusion is again and again forced upon our attention as we proceed along the line of the valley.

E. In crossing through the parallel ridges and hollows of hard and soft strata, the river is confined to steep, narrow, angularly bent passages among the hard rocks; but in the softer strata between them it flows and winds more at liberty, through wider spaces, which open far on each side, and bring additional supplies of water. In these hollows the velocity of the stream dies away, and the sediments derived from wasting of the adjoining high grounds fall on fertile meadows in floods or silt up their own channels in times of slack-water, while around appear insulated hills, left by the ancient water-currents which swept away the materials around them.

F. The river, on emerging from these ranges of secondary strata, enters a wide region of plains and low hills of gravel (*g*), rising irregularly amidst alluvial plains and marshes (*m*), amongst which, for a certain distance, the tide flows up the expanded river-channel.

Wherever these marshy plains and gravelly ridges are locally related by geographical situation and distribution to the main stream or smaller branches, so as to allow of the possibility of referring their formation to the action of the existing fluviatile and tidal currents, it would be false philosophy to look for a more remote or more general cause. This is often the case, perhaps generally so, with the alluvial sediments, for they contain often freshwater shells and other marks of limited lacustrine or fluviatile action; but it is seldom the case with the gravel beds and ridges. These often lie across the path of the river (*e e*), and often rise to a great height above it; often consist of stones not only beyond the present power of the river to transport, but such as do not occur *in situ* in any part of the area drained by its main stream or tributary waters.

Yet, from their form, distribution, and composition, there is no doubt that some have been wholly accumulated and all modified by water-currents; so that here again we have proof of the waste and remodelling of the surface of the earth by other forces than the existing atmospheric agencies.

G. On reaching the sea, we find the influence of the river prolonged into the salt-water, augmenting the mass of sediments drifted coastwise by the tide, and feebly assisting in the distribution of them. But the bed of the sea is unequal, soft, or rocky, excavated into hollows, and varied by sand-banks and gravel-beds, not unlike those on the neighbouring land, and even yielding, as they do, bones of gigantic extinct mammalia (Happisburgh coast [and in fact the eastern coast of England from Bridlington to beyond the mouth of the Thames]). These points of agreement between the actual sea-bed and the neighbouring lands mark some community of origin: the land has been raised out of the sea, and owes some of its irregularities to marine currents (as Buffon thought), or the sea's bed is subsided land. Each of these may be partially and locally true, but there can be no doubt of the sea-currents having power to alter the distribution of sand-banks and gravel-banks to some considerable, though not precisely known, depth; and as all the stratified crust of the earth has been once the bed of the sea, it is evident that the action of marine currents is a cause of universal application to the theory of the inequalities of the earth's surface, as well as of extraordinary power.

The slight sketch here presented includes phenomena which may be seen on the English rivers, though not all on one and the same stream: the description may be verified in every one of its stages a hundred times, and augmented with additional phenomena by any intelligent reader personally acquainted with the physical geography of Britain. Exactly similar phenomena, either all in the same order or variously associated, may be paralleled by instances selected from other parts of the world, and it only remains to apply a plain course of reasoning to them.

The action of atmospheric agencies, river-streamlets, and rivers, with or without lakes, with or without glaciers, is always one and the same: to degrade the high lands and to raise the low, and thus to equalise the levels, and to diminish the irregularities of the surface of the globe; and this because of the universal action of gravity, wherever there are weighty masses and inequality of level. The sea's action is similar, and though complicated by tidal fluctuations, as rivers and lakes are by drought and inundations, and by the variable influence of wind and temperature, its final results are of the same character.

This is indisputable. It is equally true that the direction of the existing watery agencies on the land is determined by the present relation of levels between the different parts of the land, and between the land and the sea. Moreover the effects of these agencies are perfectly adjusted to these levels. It follows inevitably that the sum of the effects of these existing agencies has been to diminish the original inequalities of the earth's surface, that is to say, to lower the hills, to smooth and level the valleys, to fill up the lakes, which are a part of the valleys; in a word, to change gulfs into lakes, and chasms into vales, by a mere surface action on forms which had been more boldly marked in earlier eras of nature.

We must therefore believe that immediately after the desiccation of the land, its grand chains of mountains and long continuous vales were more firmly outlined, more roughly and strongly modelled, deeper and higher than they now appear, and it only remains to inquire to what known geological causes this can be justly ascribed.

We must remember, first, that the surfaces of stratification on the sea's bed were once continuous, but on the land they are now interrupted by excavated valleys and left dismembered on residual hills: secondly, that these surfaces were plains or nearly so, and horizontal or nearly so; but now they are found contorted, ruptured, placed in angular positions, vertical, or even reversed in particular regions. The latter class of effects depends on the violent nature of the elevating movements to which the land was subject; the former is often independent of local disturbance, and seems to be due to the mere action of powerful currents of water. But it is often seen that the line of these valleys is the line of a fault, of a synclinal basin, or anticlinal ridge, that is to say, *a line of weakness*, a line of least resistance, determined by causes anterior to the current of water which, flowing up or down the line, or both up and down, has worn it into a valley.

Now if we remember that the most powerful mechanical action of water takes place on the seacoast; if we remember that, by the continual or the periodical rising of the land, this littoral action has been transferred from point to point over every part of the area of the land, beginning among the mountains at the source of the present rivers, and successively washing and wasting every part; we shall readily admit in this one universal and powerful agency the principal cause which broke the continuity of the planes of strata, washed away the least resisting and left the hardest parts, and, by successively retiring lines of action, gradually completed the main features of the valleys and hills which had not been previously impressed by violent subterranean movements.

Atmospheric agencies must be admitted to have greatly co-operated in this result, especially if, as geologists suppose, there were grounds for believing these to have been more powerful in the earlier [or in some past] eras of the world, when the temperature was perhaps higher and the atmosphere in consequence more highly vaporous. Nor must we undervalue the eroding power of modern streams, or the volume of the disintegrated earthy masses which they transport away. It is past a question that modern rivers have cut their own channels through lava (Lyell, 'Principles of Geol.'), through diluvial gravel and clay drifted from other regions (Phillips, 'Sections of the Yorkshire Coast'), and through trap thrown up by the Eifel volcanoes ([Phillips], MS., 1829). But in each of these latter instances the valley of diluvial gravel and clay lies in and conceals in part an *older valley* of ruder aspect, excavated in the stratified rocks of sandstone or limestone or argillaceous slate; and we may often contemplate in the course of one stream the fragmentary state of the rocks as left by elevatory forces, the wasting of these when they formed part of an ancient shore, the obliteration of the old valleys by some yet ill-understood cause of local accumulation, and the final adjustment of levels and slopes by causes which are still continuing this beneficent process, enlarging and enriching our meadows, contracting the areas of our lakes, and softening for the future wants of mankind the rugged features of hills which will not always defy the hand of industry.

(The reader who desires to follow out this large subject may consult with great advantage De Luc's works—as, 'Letters on Geology,' 'Lettres sur l'Hist. de la Terre et de l'Homme;' Playfair, 'Illustrations of Huttonian Theory;' Buckland's 'Reliquiæ Diluvianæ;' Lyell, 'Principles' and 'Manual of Geology;' Murchison; Darwin; [John Phillips, 'Rivers, Mountains, and Seacoast of Yorkshire']; and other modern writers. The article PARALLEL ROADS [NAT. HIST. DIV., with addition in the present article], may also be read. M. Agassiz's 'Speculations on Glaciers,' have several points of important bearing on the subject of Valleys.)

Allusion has been made in the article SURFACE OF THE EARTH, of which subject valleys constitute so important a feature, to the researches on the subject of their excavation of Mr. G. Poulett Scrope, V.P.G.S., a not less philosophical, if less popular advocate of the sufficiency of existing causes in geological dynamics than Sir C. Lyell, and to the views which his inductions from their results have led him to form. In the first volume of the 'Proceedings of the Geological Society of London,' p. 170, the reading (now above thirty years since) is recorded of a paper by that geologist, hitherto, we think, unappreciated, in which attention is drawn to the value which would attach to a test by which any one valley could be ascertained to be the result either of a rapid and violent, or of a slow and gradual excavatory process; since the forces of aqueous erosion are of a general nature, and while in activity in one river channel, were probably not idle in others. Such a test was previously pointed out by Mr. Scrope, in his work on the 'Geology of Central France,' where lava-currents which have flowed into valleys at intervals of time appear now at different heights above the actual river bed, marking the successive steps of the progress of excavation. In the paper here cited he finds another, and an equally valuable test in the extreme sinuosities of some valleys. Any sudden, violent, and transient rush of water of a diluvial character, that is, a flood of wide area, could only produce straight trough-shaped channels in the direction of the current, and could never wear out a series of tortuous flexures, through which some rivers now twist about, and often flow for a time in an exactly opposite direction to the general straight line of descent, which a deluge or débâcle would naturally have taken. Curvatures of this extreme kind are frequent in the channels of rivers flowing lazily through flat alluvial plains; these curves are gradually deepened and extended, till the extreme of aberration is corrected, and the direct line of descent restored, by the river cutting through the isthmus which separates two neighbouring curves. There are occasional instances, where the bias of the river, or direction of its lateral force of excavation has remained so constant, as to give the valley itself the utmost degree of sinuosity. But such examples must be immensely rarer than those of the configuration previously described; because the frequent shiftings of the channels of streams tend to obliterate their windings, and reduce the sum of the several successive excavations—that is, the valley—to a more or less straight form.

The valley of the Moselle, between Berncastle and Roarn, excavated to a depth of from 600 to 800 feet through an elevated platform of later palæozoic—formerly termed transition—rocks, constitutes a striking instance of the former class. Its windings are often so extreme, that the river returns after a course of seventeen miles in one instance, and nearly as much in two others, to within a distance of a few hundred yards of the spot it passed before: wearing away on either side the base of the ridge-shaped isthmus separating the curves, and enclosing a peninsula of elevated land five or six hundred feet high; but sloping *towards* the bottom of the curves, where it is strewed with boulders, left there, it may be presumed, by the river, as it gradually deepened its channel and extended its lateral curvature. The valley of the Meuse near Givet offers, through a great distance, a number of similar windings, and the same character is seen at intervals in many of the other rivers of the same physical district of Europe. Parts of the Seine below Paris, and the valley of the Wye between Hereford and Chepstow, are examples nearer home.

Valleys which like these twist about in the same regular curves as the channel of a brook meandering through a meadow, can only be accounted for by the slow and long continued erosion of the streams that still flow in them, increased at intervals by wintry floods. To attribute them to a transient and tremendous rush of water in the main direction of the valley appears to be impossible. Whilst these valleys were slowly excavated, other rivers, during the same protracted period, will have produced likewise an amount of excavation proportioned to their volume and velocity, and the nature of the rocks they flowed over. In the examples cited above, the rocks are mostly hard strata, yet the valleys are wide and deep. Where softer strata, as sands, clays, and marls, were the materials worked upon, the valleys excavated may be expected, as they are found to be, far wider in proportion to the volume of water flowing through them. The comparative softness of the materials also, by accelerating the lateral erosion of the stream, will have multiplied the shiftings of its channel, and reduced their sum with greater certainty to one average direction. Hence the deeply sinuous valleys, such as those particularised, are only found penetrating the more solid rock formations. Mr. Scrope concludes by a confirmation of his opinion that extreme curvature of channel can only be produced by a slow and comparatively tranquil process of excavation, by a reference to mountainous districts, in which, where the torrents and rivers are most rapid, their course is nearly straight; from which a legitimate converse induction arises, that a certain subdued velocity in the stream is necessary to produce the former result.

It may deserve investigation, whether the spiral course of the rivers and valleys of eastern Africa, noticed in the geographical portion of this article, may not have originated in the windings of the rivers in a former and very different geological condition of the country, of which the actual curves are the remains, after the elevation of the land into its present form.

In a paper on the elevation and denudation of the lake district of Cumberland and Westmoreland ('Quart. Journ. of Geol. Soc.,' vol. iv., pp. 70–98), Mr. Hopkins has investigated and apparently solved the problem of the origin and process of formation of the lake valleys; throwing great light on the history of similar valleys in other countries. The probable origin of the lakes, it may be remarked, that is, in the first instance, of their valleys, in diverging dislocations, was first suggested by Professor Sedgwick, but Mr. Hopkins has placed the argument in its favour, for the first time, in a determinate and demonstrative form.

It would appear impossible not to ascribe the origin of the lakes of Coniston and Windermere, for example, to the dislocations of strata, with which they are so immediately associated. Mr. Hopkins has described an enormous dislocation of the band of limestone interstratified with the older palæozoic rocks seen just above Coniston Water, producing a horizontal displacement of about a mile. The direction of the fault, as determined by a line joining the extremities of the dislocated portion of the limestone band, passes exactly down the lake. Another fault ranges down the valley of Troutbeck, as indicated by a dislocation of the limestone band, and a great horizontal displacement. It ranges accurately with that part of the lake of Windermere which lies to the south of the embouchure of the valley. On the east of Troutbeck also, there are dislocations evidently connected with the formation of the two striking valleys of Troutbeck and Kentmere. The line of dislocation would seem to pass exactly along that part of the latter valley in which the mere is situated. Indeed, according to the geologist whose views we are reciting, the existence of any of the larger lakes cannot be accounted for independently of similar dislocations. Taking Wastwater, for instance, its depth is found to be forty-five fathoms, so that its bottom is probably almost a hundred feet lower than the level of the sea. It is evident that such a basin could not be scooped out by the action of water; nor is its depth increased by an accumulation of detritus at the mouth of the valley, for the river by which its surplus water is discharged cuts into the solid rock. The lake (and its including valley), could only be formed, therefore, by a relative subsidence of its bottom, the strata being relatively displaced on opposite sides of the fault. If, in any such case, this relative subsidence do not extend to the mouth of the valley, or be less there than in the upper part of it, a lake will necessarily be formed. This general explanation will apply to all the lakes of the district.

The lakes, Mr. Hopkins concludes, are thus only "the secondary and accidental consequences of the faults with which they are associated, the primary effects being the valleys in which those lakes are situated; for, whatever may have been the agency by which the masses once occupying those valleys have been removed, it is easy to see that it would act more efficiently along lines of dislocation than elsewhere; and since the existence of dislocations along the lake valleys may be considered as established, it would seem impossible to avoid the conclusion, that those valleys must themselves have originated in such dislocations. We are thus led to conclude that a dislocation was produced before the valley began to be formed; that this led to the formation of the valley by denuding causes; and that the subsidence which caused the lake was one of the last of that series of repeated disturbances which might occur during the long interval of time which was probably necessary for the completion of the valley. . . . . This view of the origin of valleys of this kind must be considered as applicable principally in places nearest the centres or axes of elevation. In other cases they may have arisen altogether from aqueous action; or, when they originated in dislocations, they may have had their directions so altered, and their character so modified by denuding causes, as to retain no distinct traces of their origin."

From these illustrations, derived from local phenomena, we return to a part of the general history of the subject, in which again physical geography and geology are united, but remain distinct.

Whatever influence the geological constitution and lithological nature of the strata and rock-masses in which a valley has been excavated, may have upon its form, that form is still independent of what may be termed the geometrical disposition and configuration of those strata and rock-masses. This is equally true of mountains as of valleys. It seems natural to suppose that when a group of strata inclining upwards towards the same line from opposite points form what is denominated an anticlinal, a hill or a mountain should be produced; and that when a synclinal is formed by the similar meeting in one line of a group of strata inclining downwards from opposite points, a valley should be the result; and in many cases such is the fact. But in many cases also the reverse occurs, valleys being situated on anticlinal arches, and mountains consisting geologically of synclinal troughs of strata. (Lyell, 'Manual,' p. 57.) Thus it has been recently shown by Sir R. I. Murchison and Mr. Geikie ('Quart. Journ. of Geol. Soc.,' May, 1861), that the enormous mass of Ben Lawers, "like many other mountains in Scotland, as well as elsewhere," actually occupies a synclinal trough, while the deep valley of Loch Tay, like that of the Great Glen through which the Caledonian canal extends, runs along an anticlinal arch. In this manner the geographical configuration of the land is often quite different from its geological configuration, or that of its geological elements. In connection with this subject, it may be useful to advert to the manner in which the terms in question have come to be employed in modern physical geography,* and which has already led to erroneous inferences. When a geographer speaks of an anticlinal line, ridge, or axis, he simply means the ridge formed by the meeting of an upward slope and counterslope, or the imaginary line drawn through or along it; and by a synclinal, in like manner, he merely understands a linear depression or valley, formed by the meeting of a downward slope and counterslope; without reference to the geological constitution of the land having such figures. Thus geographical anticlination and synclination (derivatives employed, we believe, for the first time by Mr. Brayley), are quite different things from the disposition of groups of strata, designated by the geologists as anticlinal and synclinal. Thus, also, the slope and counterslope may consist of strata, either meeting or sloping away from each other; a difference quite unimportant in geography, but of great moment in geology. Geographers are often not geologists, and borrow appellations from the science of the latter, which they use in a sense, quite correct, of their own, but at the same time quite different from its original one.

Another and frequently occurring case of the position of a valley on an anticlinal axis is the following. In certain dome-shaped hills, or elevated regions, which all consider as having been thrust up by a force from below, there is often an elliptical cavity at the summit, due partly to the fracture of the upraised rocks, but still more to aqueous denudation, as they rose out of the sea. The central cavity is called a *valley of elevation*. It exposes to view the subjacent strata or rocks, and the incumbent stratified mass, the central portion of which has thus been removed, dips away on all sides from the axis. The structure and the theory of the production of such valleys were first recognised, and the appellation given to them, by the late Rev. Dr. Buckland, who described a remarkable instance in the valley of Kingsclere, in Berkshire, together with others, all presenting the same features of a valley, circumscribed on all sides by an escarpment, whose component strata dip outwards from an anticlinal line, running along the central axis of the valley. The most symmetrical valley of elevation in the British isles occurs in the Woolhope district in Herefordshire, consisting of two concentric narrow ranges of hills, almost continuously surrounding a broad, nearly elliptical dome; the lowest and most ancient strata forming the dome, the incumbent strata the including hills. (Buckland, 'Trans. Geol. Soc.,' series II., vol. ii.; Murchison, 'Siluria;' J. Phillips, in 'Mem. of Geol. Survey,' vol. ii.; Lyell, 'Principles,' 1853, p. 421.)

The perusal of the article PARALLEL ROADS in the NATURAL HISTORY DIVISION of this work is referred to above (col. 541), as desirable for the student of the history of valleys. Subsequently to the investigations of the eminent observers referred to in that article, and also to those of Professor Agassiz, Sir G. S. Mackenzie, Mr. R. Chambers, and others, the structure of the parallel roads of Lochaber has been carefully studied by a distinguished American geologist, Professor Henry D. Rogers, F.R.S., who occupies, greatly to the advantage of science, the chair of Natural History in the University of Glasgow. The results of this study he stated in a discourse delivered at the Royal Institution, in London, on March 22nd of the present year (1861), of which an abstract appears in the 'Proceedings;' and in which he states that he has been led by it to reject all the hypotheses hitherto offered in explanation of the terraces, as inadequate, and to recognise in certain phenomena discovered by him, but not before noticed or theoretically considered, a key to the solution of the problem. Of these we will briefly notice the principal, omitting the details, and subjoin the conclusion at which Professor Rogers has arrived.

These parallel roads are apparently level, and therefore parallel, "but further instrumental measurements," Professor Rogers remarks, "are necessary before the question of their absolute horizontality can be regarded as satisfactorily settled;" on which point, therefore, he seems to be at variance with Mr. Darwin, as well as with Sir T. L. Dick and Mr. Maclean, by whom, as stated in the former article, they were carefully levelled.

Each "road," "shelf," or "terrace," according to Professor Rogers, is a nearly level, wide, deep groove, in the easily eroded boulder-drift or diluvium [SURFACE OF THE EARTH] which, to a greater or less thickness, everywhere clothes the sides of the mountains exhibiting them. They vary greatly in their relative distinctness. With scarcely an exception, each terrace or shelf is most deeply imprinted in the hill-side, and is broadest, where the surface thus grooved has its aspect *down the glen*, or towards the Atlantic; and is faintest where the ground fronts towards the head of the valley, or the German Ocean. While conspicuous on the open sides and the westward sloping shoulders of the hills, the terraces *disappear altogether* in the recesses or deeper corries which scollop the flanks of the mountains. Each grows usually more and more distinct as it approaches the head of its own special glen, until those of the two opposite sides meet in a round spoon-like point. Each again coincides accurately in level with some "watershed" (?) or notch in the hills leading out from its glen into some other glen or valley adjoining.

The internal structure of the matter composing each terrace consists in an "oblique lamination" or slant bedding of the layers of gravel, sand, and other sediment which constitute it, such as geologists familiarly recognise as the result of a strong *current* pushing forward the fragmentary material which it is depositing, and which is held by them to indicate, in the direction towards which the laminæ dip, the direction towards which the current has moved. The "dip," or downward slant, is almost invariably *up* the glen, or towards its *head*, and *not down the glen*, or towards the Atlantic.

In all previous hypotheses, the agency of *standing* water is assumed, either the ocean in its ordinary state of repose, or lakes pent within the glens, as explained in the former article. But to these Professor Rogers opposes the facts, that these level shelves are not true marine beaches, exhibiting not a vestige of any marine organic remains, no rippled sands, no shingle, and no sea-cliffs; that they display, in like manner, a total absence of the distinctive marks of lake-sides, not one lacustrine organism, neither fresh-water plant nor animal having ever been discovered imbedded in them. Nor has any feasible cause of blockage of the glens at different stations above their mouths, to pond the waters to the respective heights of the terraces, been assigned;

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* The term anticlinal seems to have been first adopted in geography in Dr. Beke's 'Origines Biblicæ,' Lond., 1834, p. 316, where it is remarked, that the range of mountains called the Karadjeh Dagh, "forms the geographical anticlinal line between the two great rivers Tigris and Euphrates, and their respective tributary streams."

there are no traces of former barriers in any of those localities where alone we can assume them to have existed, to produce the required embaying of the waters. The hypothesis of successive "sea-margins," or sea-levels, is stated to be overthrown by the now well-established deduction from the recent measurements of Professor Rogers himself, that none of the several shelves, or "roads" of Glen Roy correspond in level with any of those seen in the adjacent valley, Glen Gluoi, a marked discrepancy separating the two groups of terraces into two independently produced systems.

After adducing further objections, both of fact and reasoning, to former hypotheses on the origin of the parallel roads, Professor Rogers concludes by sketching, in the following terms, the action to which he ascribes their formation:—"He supposes the several terraces to have been cut or grooved in the sides of the hills by a great inundation from the Atlantic, engendered by some wide earthquake disturbance of the ocean's bed, and forced against the western slope of Scotland. The features of the country indicate that, while a portion of such a vast sea-tide entering the Frith of Linnhe rushed straight across the island through the deep natural trench, Glen Mor or the great Caledonian valley, a branch current was deflected from this, and turned by the Spean valley and its tributary glens, Glen Roy and Glen Gluoi, into the valley of the Spey, and so across to the German Ocean. In this transit, the deflected waters first embayed in these glens, and then filling and pouring through them, would, upon rising to the levels of the successive water-sheds, or low passes, which open away to the eastern slope of the island, take on a swift current through each notch, and as long as the outpour nearly balanced the influx, this current, temporarily stationary in height, would carve or groove the soft "drift" of the hill-side. But the influx increasing, the stationary level and grooving power of the surface-stream would cease, and would only recommence when the flood rising to the brim of another natural dam, a new equilibrium would be established, a new horizontal superficial current set in motion, and a second shelf or terrace begin to be eroded at the higher level. So each of the parallel roads is conceived to have been produced in the successive stages of the rising of one vast steady incursion of the sea. The lapsing back of the waters, unaccompanied by any sharp localised surface-currents through the passes, could imprint no such defined marks on the surface, nor accomplish more than a faint and partial obliteration of the terraces just previously excavated during their incursion."

A succinct view of the controversy respecting the formation of the parallel roads, showing the position of the subject prior to Professor Rogers's investigation, will be found in Sir C. Lyell's 'Manual of Elementary Geology,' 5th ed., 1855, pp. 86–89.

VALUE signifies, in political economy, the quantity of labour, or of the product of labour, which will exchange for a given quantity of labour or of some other product thereof. It is necessary in the outset to distinguish utility from value, or, as Adam Smith expresses the distinction, "*value in use*" from "*value in exchange*." The utility of an article causes it to be an object of demand; and without some real or imaginary utility an article will not have value; or, in other words, no one will give other articles in exchange for it: but utility alone does not constitute value, except when there is a limited and exclusive possession, which enables one man to refuse to others the enjoyment of any natural product without the payment of an equivalent or price. It is the labour of man alone which in ordinary circumstances creates value. What all may enjoy alike without labour may indeed be most useful and necessary, but cannot be an object of exchange, and therefore is destitute of value. "The real price of every thing," says Adam Smith, "what everything really costs to the man who wants to acquire it, is the toil and trouble of acquiring it. What everything is really worth to the man who has acquired it, and who wants to dispose of it or exchange it for something else, is the toil and trouble which it can save to himself, and which it can impose upon other people." Hence the labour of man becomes the real measure of the exchangeable value of all commodities.

To illustrate the distinctive character of utility, and the effects of labour and of exclusive possession respectively upon value, suppose a party of settlers to occupy a tract of land, and to divide it amongst them in equal portions by lot. Suppose also that each settler has upon his own land timber, lime, and stone. They all need houses, and have the materials to build them with; but the unaided labour of each man is unable to appropriate and apply the materials in the manner he desires. One man calls in the assistance of his neighbour, and by their joint labour a house is built; and this service he repays by helping his neighbour also to build a house. He can only repay him by labour, because the materials, though of the highest utility, are common to both, but need labour to make them available. It is clear that the timber, the lime, and the stone are in this case without value, and could not be offered by one man in exchange for the labour of another. But suppose it should happen that all the timber, lime, and stone in the whole district should be found in the portion of land allotted to one of the party. Here the materials would not only be objects of utility, but the limited and exclusive possession of them would endow them with value. The fortunate owner of them might say to his neighbours, "You shall not have any of my materials until you have first built me a house; but when you have each worked for me a day, instead of repaying each of you with a day's labour myself, I will permit you to take the materials for building from my estate." Here the power of withholding the products of nature from others is productive of value, being equivalent to a certain quantity of labour. But even in this case it is labour which creates the value, and is the measure of exchange between the parties.

The great mass of commodities which are made the subject of exchange amongst men are produced by labour only, and are not affected by any exclusive possession whatever. With these therefore the quantity of labour used in their production is the measure of their real value. They will ordinarily exchange for other commodities upon which an equal quantity of labour has been expended; but there are circumstances which may affect their exchangeable value, while their real value or cost of production may remain the same. If a larger quantity of any article has been produced than there is an effective demand for, its exchangeable value is reduced; if on the contrary, its supply is unequal to the demand, its value is raised. But these variations cannot be of long duration. Articles which do not repay the cost of production will soon cease to be produced, until the diminished supply has again raised their value; and when articles bear a market value much higher than their cost, production will be encouraged until the supply is not very wide of the demand. Any permanent alteration, therefore, in the exchangeable value of one commodity as compared with another, cannot be referred to these fluctuating and accidental causes, but must be the result of a change in the real value of one or the other, that is to say, in the quantity of labour required to produce it. The value of labour is always the same, but the value of the products of labour changes with circumstances.

The real value of a commodity having been shown to be dependent solely upon the quantity of labour necessary for its production, and the exchangeable value, for the causes stated, never varying materially either above or below the real value, it follows that the price paid for labour does not affect the exchangeable value of articles produced under similar circumstances. If the labourer gains a larger share, the profits of his employer are proportionately diminished; and if his share is less, then profits are increased: while both are generally preserved by competition from any great disproportion.

Equal quantities of labour however are not always equivalent; the skill of one labourer, or the severity of his employment, may render the time for which he is engaged more than equivalent to the same time occupied in labour by another. But this circumstance, though it originally affects the comparative value of commodities produced by different descriptions of labour, is no cause of subsequent variation in their relative value. The relations of different qualities of labour are soon practically adjusted, and are not afterwards liable to much variation.

Every reduction in the quantity of labour required to produce a commodity diminishes its real value, and therefore, for the causes already explained, its value in exchange. Improvements in tools and machinery, by saving the labour of man, reduce the value of commodities; but in estimating their influence, we must not omit to calculate the quantity of labour bestowed upon the article, directly and indirectly—from the growth of the raw material to its finished state—throughout the whole process of manufacture—upon the tools, machinery, buildings, and other appliances by which labour is assisted. Upon the same principles every increase in the quantity of labour directly or indirectly applied adds to the value of a commodity.

The amount of capital employed also enters into the computation of value. Capital is only accumulated labour. Where it is abundant a small interest is accepted, but where it is scarce a larger portion of interest has to be added. Labour can hardly ever be profitably exerted without the intervention of capital, as the labourer must be provided with subsistence until his labour has realised a profit. All improvident attacks, therefore, of the labourer upon the labour fund by lessening the amount of capital to be advanced for his support in view of prospective realisation, must inevitably react upon himself to his own disadvantage.

The effects of labour upon price become further complicated by the durability of the machinery employed to assist it. If two commodities are produced by machinery at an equal cost of labour, and if the same quantity of labour has also been bestowed, in each case, upon the machinery—the value of such commodities would appear to be the same; but if one machine wears out in two years or needs much labour to keep it in repair, while the other lasts for ten years requiring but little repair—the relative quantities of labour expended indirectly upon the two commodities become so unequal, that a considerable disproportion must be found in their respective degrees of value.

Disturbances of the relative value of different commodities apparently produced by the same amount of labour, are also caused by the comparative quantities of fixed and circulating capital employed, and by the length of time over which the labour is spread, and before the products are brought to market. Under these varying circumstances in the production of articles, the price of labour becomes an element in their relative value, which is not the case when commodities are produced under precisely similar circumstances. If all commodities were produced by an equal proportion of fixed and circulating capital, any rise or fall of wages would affect them all equally, and would not therefore disturb their relations to each other. If a yard of woollen cloth, for instance, exchanged for a yard of silk, and wages rose, the value of each would rise in an equal proportion, and the articles would continue to exchange for each other as before. But if the cloth were produced almost entirely by machinery and the silk entirely by manual labour, a rise of wages would scarcely affect the former at all, while it would add materially to the cost of producing the latter. They would therefore no longer exchange for each other, or, in other words, their relative value would be altered. The general law of such variations is thus stated by Mr. Ricardo, namely, that in the event of a rise in the price of labour, "only those commodities would rise which had less fixed capital employed upon them than the medium in which price was estimated, and that all those which had more would positively fall in price when wages rose. On the contrary, if wages fall, those commodities only would fall which had a less proportion of fixed capital employed on them than the medium in which price was estimated; all those which had more would positively rise in price."

With all these causes of disturbance in the relations which the different products of labour bear to each other, it is obvious that no commodity can be a perfect standard by which to compare the variations in the value of other commodities; but as, in an advanced stage of society, labour cannot be the ordinary measure of value, some representative of labour must be selected, by which to carry on the exchanges of trade, and the more nearly it represents the amount of labour expended upon it, and the less that amount varies, the fitter will it be for a common standard of value.

The precious metals, or paper convertible into them, are the standards usually adopted. They are however articles of commerce varying in supply and demand, and in the quantity of labour required, at different times, to produce them. They cannot therefore be invariable standards, but must fluctuate more or less like other commodities. Practically, this variation is not, upon the whole, so great as in the case of other articles, but in the degree in which it prevails it makes gold and silver imperfect standards of value. The circumstances and results of this imperfection and the means of obviating them are among the most important speculations of the political economist, but are more fitly treated of in other parts of this work. [Bank; Banking; Currency; Exchange; Wages.]

(Adam Smith, *Wealth of Nations;* Ricardo, *Principles of Political Economy and Taxation;* Mill, *Elements of Political Economy;* Say, *Richesse des Nations.*)

VALVASOR. [Vavasor.]

VALVE. A moveable partition introduced in machinery for the purpose of alternately opening and closing a passage through which steam or water may be intended to pass, is called a *valve;* and this generic name receives many specific designations according to the position, or the function, the valve may be required to occupy, or to perform. Thus there are head, or feet valves; suction valves; delivery, discharge, air-pump, steam, safety, blow-off valves; spindle, clack, flap, slide, cup, crown valves; stop, expansion, distribution, equilibrium, and countless other varieties of valves, which can only be described in the detailed notices of the machinery of which they form part. It may suffice, then, to state here briefly, that the conditions a valve is required to fulfil are, that it shall open freely in the required direction; that it offer no obstruction to the passage of the fluid it is designed to pass when it is open; that when it is closed it shall not allow the fluid to return. Valves must, therefore, fit closely on their seats; be sufficiently strong to resist the pressure to which they are to be exposed; they must be composed of materials which should not be likely to suffer deterioration or wear; they must be accessible at any time for examination and repair. In the exceptional forms of throttle-valves, the majority of the last-named conditions apply; though, of course, as those valves are not intended effectually to close the passage of the fluids they intercept, they do not require the same amount of strength, or the same perfection in the seating, as the ordinary valves do.

It follows, from the nature of the work performed by ordinary valves, that great mechanical perfection is necessary in their execution. The bearing surfaces are, therefore, carefully planed, turned, and fitted; and the face of the valve itself is frequently covered with a semi-elastic material, for the purpose of more effectually excluding the passage of the fluids; or it may be kept close against the seating by means of springs. These contrivances, however, necessarily give rise to considerable friction on the opening and shutting of the valves, and it thence becomes necessary, in designing machinery, to diminish the weight and the number of the valves as much as possible. Moreover, as valves only open when the pressure on one side exceeds that upon the other, the effort required to open them may become a question of serious importance, and the reaction which may ensue upon their being suddenly closed may frequently exercise a powerful effect upon the solidity of the machinery; as for instance, in the cases of a valve upon the rising main of a large pump, or of the expansion gear of a steam-engine. It is for the purpose of obviating these sources of inconvenience and danger, that the cup-valves and the equilibrium-valves, before alluded to, under Pump and Steam-Engine, are introduced; for ordinary purposes it may be considered that *lifting*-valves are adapted for rough work and for dense fluids; that *hinged*-valves present some mechanical advantages over the lifting-valves; and that when there is a necessity for gradually closing a passage, or for preventing the escape of a rare fluid, the *sliding*-valves should be resorted to.

Flap-valves, and screw-valves, are occasionally used in hydraulic engineering; the former, for the purpose of securing an autonomic discharge of drainage waters whenever the internal pressure on the valve shall exceed the external pressure; and the latter, for the purpose of intercepting the flow of water, or even of gas, in pipes. Self-acting balance-valves are often used for ventilation, and occasionally for the purpose of regulating the draught in furnaces, chimnies, &c. A very ingenious system of self-acting balance valves was introduced by Mr. Thom in the Greenock Water Works, to ensure the uniformity of flow of the mill streams he had there to deal with: a full account of these contrivances is to be found in the 'Annales des Ponts et Chaussées' for 1831.

VALYL. [Butyl.]

VAMPIRE. According to Dom Calmet's 'Dissertation sur les Vampires,' the vampire is a dead man, who returns in body and soul from the other world, and wanders about the earth, doing every kind of mischief to the living. Generally he sucks the blood of persons asleep, and thus causes their death. Those who are destroyed in this way become vampires. The only manner of getting rid of such unwelcome visitors is, according to the same author, to disinter their bodies, to pierce them with a stake cut from a green tree, to cut off their heads, and to burn their hearts.

The belief that the dead sometimes return to this world, in order to annoy the living, was prevalent in very early times. Eastern nations have a similar superstition about malicious ghosts, called "gouls," &c. The belief in these apparitions was not destroyed by the introduction of Christianity, but remained, like many other superstitions bequeathed by paganism, in full force during the middle ages. The laws of Charlemagne ('Capitularium pro Partibus Saxoniæ') contain certain enactments respecting apparitions called Striga or Masca (this last word signifies a shapeless being). This circumstance proves the generality of this belief during that period.

The advance of civilisation in modern times was unable to destroy a superstition founded upon a feeling by which the great mass of mankind is so frequently actuated—fear; and many authors wrote books on the subject. Besides Dom Calmet, whom we have quoted, we may mention—Philip Rerius, an author of the 17th century; Michael Rauft, who published in the last century a treatise 'De Masticatione Mortuorum in Tumulis;' Ferdinand von Schers, 'In Magia Posthuma,' Olmütz, 1706, &c.

The superstition about the vampires is chiefly prevalent in some parts of Eastern Europe. These apparitions are known in Poland under the name of "Upior;" in the Ukraine, "Upeer;" in Russia, "Googooka;" in Hungary, Servia, Greece, &c., "Vroucolackas," "Vardoulacka," "Broncolucka," &c.

Of all those countries, Hungary and its dependencies may be considered as the principal seat of vampirism, and little more than a century has elapsed since all Europe was filled with reports about the exploits of vampires in Hungary and Servia. It was during the five years from 1730 to 1735 that vampirism reached its height. It was so general, that Louis XV. of France commissioned his ambassador at Vienna, the Duc de Richelieu, personally to ascertain, in Hungary and other Austrian dominions, the reality of vampirism. The French diplomatist denied in his report to the king the existence of the vampires, and he informed him at the same time that the anecdotes about them were inserted in the contemporary records of the Austrian tribunals. This superstition gained ground so much that the chief periodicals of that time contain accounts of cases of vampirism in Hungary; such as, for instance, the 'Mercure Historique et Politique,' for October, 1736, pp. 403, 411; and the Dutch paper, 'Le Glaneur,' No. ix., for 1733.

A great number of anecdotes, many of which had been officially registered, are related by contemporary writers; some of them even described the manners and customs of those vampires; as for instance, that lying in their graves they suck and chew their winding-sheets, and that it was therefore necessary to place under their chins a piece of green turf in order that they might not be able to reach the sheets with their teeth, and to bind their hands, that they might not turn about in their coffins. Many believe that the vampires, notwithstanding all the means used to destroy their bodies, will resume their shape, and recommence their mischievous wanderings as soon as the rays of moonlight fall on their graves. This superstition is chiefly prevalent in Greece, and the tale of 'The Vampire,' written by Dr. Polidori, was founded upon it.

It may be supposed that the superstition about the vampire has derived considerable strength from cases where men, supposed to be dead, have been buried alive. Such cases have happened in many countries, as has been shown by the altered position of the body in the coffin, spots of blood on the torn winding-sheets, bites on the hands, and other marks of the struggle and despair before life became extinct. It is probable that such signs have been sometimes interpreted as the marks of vampirism.

VANADIC ACID. [Vanadium.]

VANADIUM (V). A rare metal. It was discovered in 1801 by Del Rio, and in 1830 named, by Sefström, Vanadium, from *Vanadis,* a cognomen of the Scandinavian goddess *Freia.* In exceedingly minute quantity it exists in nearly all clays, but occurs in abundance in a lead ore (vanadiate of lead) found at Wanlockhead in Scotland, Zimapan in Mexico, and recently in Chili.

By reducing vanadic anhydride with potassium, and digesting the product in water, vanadium is obtained as a brilliant, metallic powder; soluble in nitric acid or aqua regia, but unacted upon by boiling sulphuric, hydrochloric, or nitric acids.

The equivalent of vanadium is 68·46.

Vanadium and *oxygen* combine in three proportions. The *protoxide* (VO) has the appearance of graphite, and is formed when hydrogen is passed over heated vanadic acid. The *binoxide* (VO_2) is a black powder produced when the protoxide is heated in the air; it combines with acids to form salts, which have a blue colour. The *teroxide* or *vanadic anhydride* (VO_3) is a brownish-red powder that remains on heating bivanadiate of ammonia. It fuses at a red heat, and is slightly soluble in water, to which it communicates a yellow tint and an acid reaction. *Vanadic acid* ($2\,HO, VO_3$) falls as a precipitate when nitric acid is added to a hot solution of a bivanadiate; in appearance it much resembles hydrated oxide of iron. Dried over sulphuric acid it loses an equivalent of water, and *protohydrate* (HO, VO_3) remains.

Vanadiates are obtained on decomposing bivanadiate of ammonia by a chloride. They contain—

Bivanadiate of soda	$NaO, 2VO_3 + 9HO$
„ strontia	$SrO, 2VO_3 + 9HO$
„ lime	$CaO, 2VO_3 + 9HO$
„ magnesia	$MgO, 2VO_3 + 8HO$
Baryta salt	$3BaO, 5VO_3 + 19HO$

To produce bivanadiate of ammonia Hauer recommends that the crude vanadium compound be calcined, the residue digested in water, the insoluble portion fused with nitrate of potash, the resulting mass digested in water, the solution concentrated, and vanadiate of ammonia precipitated by adding excess of chloride of ammonium; it is purified by repeated crystallisations from water containing acetic acid.

Two *chlorides* (VCl_2 and VCl_3), as well as sulphides, bromides, iodides, and fluorides of vanadium, have been obtained.

Tests for Vanadium. By reducing agents, such as sulphide of hydrogen, or a boiling mixture of sulphuric acid with alcohol or sugar, vanadiates yield beautiful blue solutions. This reaction distinguishes them from chromates, which under the same circumstances give green liquids.

VANDALS. [Teutonic Nations.]

VANILLA, [Vanilla, *Aromatica*, in Nat. Hist. Div.] is a native of Brazil. The fruit is the only part of the plant that is used. It has a balsamic odour, and a warm agreeable flavour. For these properties it is indebted to a peculiar volatile oil, and to a considerable quantity of benzoic acid. The fruit is gathered when it gets yellow, and it is first allowed to ferment for two or three days: it is then laid in the sun to dry, and when about half dried it is rubbed over with the oil of cocoa: it is again exposed to the sun to dry, and oiled again a second time. The fruit is then collected in small bundles, and wrapped up in the leaves of the Indian reed, and sold to the Europeans. It is used to flavour chocolate.

VANISH (Mathemátics). A quantity is said to vanish, or to become evanescent, when its arithmetical value is nothing, or denoted by 0. When the evanescent quantity is only a part of another, there is seldom or never any more difficulty about the case in which it vanishes than about that in which it takes any other specified value: but when the whole of what is under consideration vanishes, any or all of those views may be required to render this case intelligible which are explained in Nothing; Infinite; Limits; Ratios, Prime and Ultimate; &c. And in particular the phrase of two quantities vanishing in a certain ratio is to be referred to the last of the articles cited. When a value given to a letter makes an expression vanish, or reduces it to 0, it would be very convenient to say that the given value *nullifies*, and is a *nullifier* of the expression: but this language is not used.

VANISHING FRACTIONS. [Fractions, Vanishing.]

VANISHING POINT, LINE, &c. [Perspective.]

VAPORISATION is the process by which a liquid on being sufficiently heated passes off in the form of vapour. It differs from Evaporation in being generally an artificial and a quicker process, while the latter is spontaneous.

VAPOUR. There are many substances, both fluid and solid, which when exposed to the air, or to the more powerful agency of heat, are gradually but totally dissipated, owing to their particles assuming the state of vapour by what is termed *spontaneous evaporation.* A vapour, then, consists of ponderable matter combined with sufficient specific heat to enable it to retain its aëriform existence: we have already [Gas] given a similar definition of a gas. The question, then, naturally arises, In what do vapours differ from gases? The answer is, that the difference is a conventional one, being of degree only, and not of kind: thus, when atmospheric air containing, as it always does, the vapour of water, is suddenly cooled by exposure to a colder substance, the water which it contained in the state of invisible vapour is deposited in the state of palpable water on the colder body; we say then aqueous vapour or the vapour of water, and not aqueous gas. No similar change is produced, by this abstraction of heat, in the form of the constituents of the air, and they are therefore termed gaseous bodies or gases. The difference, however, we repeat, is one of degree only; for many gaseous bodies which had been, not many years since, considered as permanently elastic as atmospheric air, have been shown by the important investigations of Dr. Faraday to be reducible to liquids [Gases, Liquefaction of]; and additional experiments have even shown that carbonic acid gas, which requires a pressure of 35 atmospheres to render it fluid, may by particular management be converted into a solid. [Carbonic Acid.]

A practical difference between a vapour and a gas is illustrated by the use of the vapour of water, and its subsequent condensation, as a motive-power in the steam-engine. [Steam and Steam-Engine.] No known gaseous body could be employed with the same advantage, owing to the great degree of pressure and cold required for its condensation. Nor could the vapour of any other liquid than water be so profitably employed as a prime mover, for the reason given under Latent Heat.

It was formerly supposed that the air dissolved vapour and held it in solution as water holds sugar or salt. This was the theory of Le Roi, propounded in some otherwise ingenious papers, 'Sur l'Elévation et la Suspension de l'Eau dans l'Air et sur la Rosée.' ('Mem. Acad. Royale des Sciences,' 1752; and also in a separate volume, 'Mélanges de Physique et de Medicine,' 1771.) This theory, however, was completely demolished by Dalton at the commencement of the present century ('Manchester Memoirs'), who showed that a vapour forms much more easily in a vacuum, and that the pressure of air retards and obstructs the evaporation of a liquid. Dalton's apparatus consisted chiefly of two barometers placed side by side. A drop of a given liquid was sent up into the vacuum of one of them, when it became converted into a transparent vapour, and, exerting a pressure on the mercurial column, lowered the mercury in the tube. The amount of this depression was measured by comparison with the adjacent barometer, and the elasticity of the vapour was expressed not by that depression, but by an equal quantity of mercury which the vapour would support. Thus, if the summit of the column of the mercury containing the vapour stood half an inch below the mercury in the adjacent barometer, the pressure of the vapour would be such as would support a column of mercury half an inch in height. In estimating this pressure, sufficient liquid must be sent into the vacuum to saturate it, and it is then found that the elasticity of the vapour is directly as the temperature. By surrounding the tube with some vessel capable of containing hot water, with a thermometer for indicating temperature, the temperature of the vapour can be known, and the relation between its temperature, pressure, and density ascertained. [Evaporation.] Various forms of apparatus have been contrived by Dalton, Gay-Lussac, Arago, and Dulong, and by Regnault, for determining the pressures and densities of vapours, and obtaining such results as are given in the table under Steam and Steam-Engine.

The specific gravities of vapours, like those of gases, are referred to air as a standard at the temperature of 32° and a pressure of 30 inches; or the density of a vapour may merely express the ratio of a given volume to an equal volume of air of the same temperature and pressure. In the case of steam above 250° this ratio is invariable, and indeed the ratio of the densities is constant for the vapour of most liquids above their boiling points. These ratios have been thus determined by Gay-Lussac:—

Air	10,000
Vapour of water	6,235
„ alcohol	16,138
„ sulphuric ether	25,860
„ sulphuret of carbon	26,447
„ essence of turpentine	50,130
„ mercury	6,976
„ iodine	8,716

When a gas and a vapour which do not act chemically on each other are inclosed in the same space, they will exert separately on the sides of the vessel the same pressures that each would produce if it occupied the same space in the absence of the other, so that the total pressure of the mixture is equal to the sum of the separate pressures.

When vapour receives a supply of heat after it has been separated from the liquid it is called super-heated vapour. Such vapour, unlike ordinary vapour, may lose a portion of its heat, and still the whole of it continue to be vapour. If, after a vapour has been raised from a liquid, it be compressed into a smaller space, its temperature will rise, and if expanded it will fall; but the temperature, pressure, and volume will always be such as the vapour would have had if it had been raised directly from the liquid at such temperature and pressure. Thus, vapour raised from water at 68° has a volume 58·224 times greater than the water that produced it. If this vapour be separated from the water, and its volume be compressed until it is only 1696 times that of the water, its temperature will rise to 212°, or that which it would have had if directly raised from the water under the increased pressure.

Evaporation, both spontaneous and artificial, and especially the latter, is employed in numerous manufacturing and chemical processes. When, for example, common salt is prepared from sea-water, it is exposed in the first instance to the air in shallow clay pits, by which spontaneous evaporation takes place; and this occurs to the greatest extent in hot weather, and when the surface of the brine is agitated by the wind. It is found, however, that spontaneous evaporation can be carried on with advantage to a certain extent only; and when this point is arrived at, the operation of salt-making is finished by removing the concentrated brine to iron vessels, in which the evaporation is artificially conducted by the application of heat, the vaporisation being greater as the temperature is higher, till the boiling-point is arrived at, when it is greatest.

Evaporation is used for numerous purposes and processes, and in different modes, according to the substances operated on and the objects to be attained. When contrivances are adopted for condensing the whole or any portion of an evaporated liquid, the process is termed Distillation, and the ends accomplished by it are various. When, for example, water is distilled, it is for the purpose of separating the saline and earthy impurities, which, not being vaporisable, remain in the body of the still, while the pure vapour of the water is condensed by cooling in the worm: so, again, when wine is submitted to distillation, it is for the purpose of evaporating and subsequently condensing the spirit or brandy from the water and the colouring-matter. When herbs, as lavender, peppermint, &c., are heated with water in a still, the oil and water rise in vapour and are condensed; when turpentine is similarly treated, a volatile oil rises in vapour, while the resin or rosin, not being volatile, remains in the still. Vaporisation in the form of distillation is also largely employed in the preparation of various acids, such as the nitric acid, hydrochloric acid, &c.

When solid bodies are vaporised and subsequently condensed, the operation is termed *sublimation*, and it is resorted to with different intentions, as for the purification of camphor and the preparation of corrosive sublimate and calomel.

It will be evident on slight consideration that vessels of very different materials and construction must be employed in evaporation, distillation, and sublimation, and according to the nature of the substance operated on. Thus the first stage of the concentration of sulphuric acid is conducted in lead, the concluding one in glass or platinum; saline solutions are evaporated to the crystallising point in lead or copper; the caustic alkalies in iron or silver; the distillation of spirits in copper; that of acids in iron, earthenware, or glass; while the preparation of common salt is completed in vessels of iron.

For further information we refer to Evaporation; Dew; Hygrometry; Boiling of Liquids; Ebullition; Distillation; Steam and Steam-Engine; Latent Heat; Specific Heat; Transpiration.

VAPOUR-BATH. [Bath; Bathing.]

VAPOUR, OPALESCENT. This appears to be the most convenient appellation for what has sometimes been termed red or orange steam. It is a condition of condensed and condensing aqueous vapour which was first distinctly recognised, and its optical properties investigated by Dr. James D. Forbes, F.R.S., when Professor of Natural Philosophy in the University of Edinburgh. Its effects in nature have been observed from time immemorial, though ascribed to other causes; and there can be no doubt that it would long ago have been recognised and described by those practically conversant with steam and steam-engines, had not its effect on luminous bodies been confounded with that of smoke, from which it is in fact undistinguishable by the eye. In the year 1838, Professor Forbes, standing near a locomotive engine which was discharging a large quantity of high-pressure steam by its safety-valve, chanced to look at the sun through the ascending column of vapour, and was struck by seeing it of a very deep orange colour, exactly similar to dense smoke, or to the colour imparted to the sun when viewed through a common smoked glass. The same he found might be observed during the ordinary progress of the engine in the steam thrown into the chimney, but the presence of smoke itself rendered the experiment less satisfactory. He afterwards observed that while for some feet or yards from the safety-valve at which the steam blows, its colour for transmitted light is the deep orange red, at a greater distance, the steam being more fully condensed, the effect entirely ceases. Even at moderate thicknesses the steam cloud is absolutely opaque to the direct solar rays, the shadow it throws being as black as that of a dense body; and when the thickness is very small it is translucent, but absolutely colourless, just like thin clouds passing over the sun, which indeed, according to Professor Forbes, have a perfect analogy of structure. When the steam is in this state no indication of colour is perceptible in passing from the thickness corresponding to translucency to that which is absolutely opaque.

Professor Forbes proceeded to investigate this novel subject by means of a high-pressure steam-boiler, and a theodolite with a good prism placed in front of the telescope, and from the experiments he made deduced the following conclusions:—"1. Steam in its purely gaseous form is, as commonly supposed, colourless, at least in small thicknesses. 2. The orange-red colour of steam by transmitted light appears to be due to a particular stage of the condensing process. Before condensation steam is colourless and transparent; it is next transparent and smoke-coloured; finally it becomes colourless at small thicknesses, and absolutely opaque at greater. 3. The state of tension of the steam seems only to affect the phenomena so far as it renders the critical colorific stage of condensation more or less completely observable. 4. The absorptive action of steam on the spectrum is not exerted in the same way as that of other gaseous coloured bodies, such as nitrous acid gas, and iodine vapour. It cuts off, however, totally the same part of the spectrum as nitrous acid does. Its phenomena perhaps have a greater analogy to those of opalescence than any other." 'Phil. Mag.,' series 2, vol. xiv., p. 121-126; the paper having been read before the Royal Society of Edinburgh, on January 21, 1839.

The combination of a variety of other facts with those thus made known by Professor Forbes, relating to the nature and properties of condensing steam with respect to light, have subsequently led other men of science to unite in the conclusion, that the structure of orange steam is in reality that of opalescent bodies, with the phenomena of which, as we have seen, he recognised the analogy of those presented by it. Innumerable globules of water are formed throughout the still gaseous vapour, by the joint action of which on light the colour of the aggregate mass is produced. It is on this account that its absorptive action on the spectrum is not exerted in the same way as nitrous acid gas and iodine vapour, which themselves possess true colour. The other results obtained by Professor Forbes also harmonise with this conclusion.

But though we are thus obliged to relinquish the idea that aqueous vapour in any state is itself truly coloured, the observation of the existence of this particular condition of a condensing volume of steam is of great value; especially in its application to the phenomena of nature. Professor Forbes at once inferred from his investigation of it, that the condition of watery vapour he had observed "is the principal or only cause of the red colour observed in clouds;" and he is entitled to the credit of being, in fact, the discoverer of the true cause of the colours of dawn and sunset. In a subsequent elaborate communication 'On the Colours of the Atmosphere,' he investigated the history of science on this subject, refuting the fallacious inferences which had prevailed, and applied to it his own observations. "Soon after the maximum temperature of the day, and before sunset," he remarks, "the surface of the ground, and likewise the strata at different heights in the atmosphere, begin to lose heat by radiation; this is the cause of the deposition of dew, and consequently in severe weather we have vast tracts of air containing moisture in that critical state which precedes condensation,"—in other words, in the red opalescent condition, by which the rays of the setting sun are coloured accordingly. For the details of this subject we must refer to Professor Forbes's paper in the 'Trans. of the Royal Society of Edinburgh,' vol. xiv. But we cannot wholly agree with him as to the colours of the morning sky, the phenomena of which appear to us to be the same with those of the evening, but in the reverse order. Mr. Luke Howard had long before observed the connection of the presence in the sky of a stratum of vapour having the peculiar red colour, with the coming or actual formation of dew, and had given to it the name of the *dew-band*, of which many observations will be found in his 'Climate of London.'

VAPOUR-PLANE. This term, which was probably adopted by Luke Howard from De Luc, denotes a region of the atmosphere horizontal in its general direction, though subject to elevations and depressions, at or on and above which clouds form by the condensation of aqueous vapour, and on which, therefore, they appear to float. Its position is most readily recognised by the eye, by observing the modification of cloud called *cumulus*, the various aggregations of which, or distinct clouds, have a common base-line, or have their inferior surfaces at the same height. The subject has already been noticed in the articles Cloud (col. 981) and Dew-Point; but in the latter the vapour-plane is erroneously stated to be the superior, instead of the inferior, limit of a certain stratum of the atmosphere, and also that cloud forms below instead of above it, when it is regarded as a mathematical plane. But there are in fact as many vapour-planes in the atmosphere of any locality on the earth's surface, and at any time, as there are strata of clouds at different elevations; and in each case the plane becomes itself a physical plane, or stratum, throughout which cloud is produced. These successive strata originate, of course, in alternations of temperature and in the amount of aqueous vapour present in a given volume of air.

The following statement, founded upon the principal results deduced by the late Mr. J. Welsh from experiments made by him and described in his account of meteorological observations in four balloon ascents made in 1852 ('Phil. Trans.,' 1853, pp. 311-346), already cited under Cloud, gives a general view of the nature of the alternations in question, which may be compared with the particulars of the height of the several strata of cloud passed through in those ascents, and stated in that article, col. 983.

The temperature of the air decreases uniformly with the height above the earth's surface, until, at a certain elevation, varying on different days, the decrease is arrested, and for a space of from 2000 to 3000 feet the temperature remains nearly constant, or even increases by a small amount, the regular diminution being afterwards resumed and generally maintained, at a rate slightly less rapid than in the lower part of the atmosphere, and commencing from a higher temperature than would have existed but for the interruption noticed. This interruption in the decrease of temperature is accompanied by a large and abrupt fall in the temperature of the dew-point, or by actual condensation of vapour, from which it may be inferred that the disturbance in the progression of temperature arises from a development of heat in the neighbourhood of the plane of condensation, or *vapour-plane*. The subsequent falls in the temperature of the dew-point are generally of an abrupt character, and productive of as many vapour-planes; corresponding interruptions in the decreasing progression of temperature are sometimes distinguishable, but in a less degree, as might indeed be expected from the fact that at greater elevations, and consequently lower temperatures, the variations in the absolute amount of aqueous vapour are necessarily smaller, and their thermic effects consequently diminished.

VAREC. An obsolete name for crude carbonate of soda.

VARIABLE. A quantity is said to vary when it changes value, whether gradually, or by jumps or starts. The notion of a variable quantity is the first which must be established in teaching the Differential Calculus, and requires a little explanation.

One magnitude at least is hardly conceivable without the notion of variation; we mean time or duration. Reckoning from a fixed epoch, the idea of *the present time* is nothing but that of the other extremity of a variable quantity, the variation of which we cannot suspend, even in thought. Again, in space-magnitudes, though we are not obliged to consider them as formed by variation, yet it is in our power to do so, and we are constantly learning the variation of length, area, or solidity consequent upon motion. And we can even consider this variation as arising from no act of our own, as independent of us, and out of our power to stop: though even when this is physically true, namely, that the variation is out of our power, we can conceive or imagine that it does stop, and trace the consequences of such stoppage. Variable *magnitude*, then, presents natural ideas, such as we not only easily acquire, but such as it would be difficult, if not impossible, to suppose that we could help acquiring.

But when we come to speak of *number*, the case is much altered. The constant phrase of an algebraist, "let x be a variable quantity," clear as it may be when quantity means magnitude, is not quite so plain when quantity means number as the representative of magnitude. There is something to be said as to how number is imagined to vary at all: and still more as to its *gradual* variation.

Number is an abstraction of the mind; it is not magnitude, but a mode of reference of one magnitude to another. If we might dare to say it, number is more of the nature of an opinion about magnitude than of magnitude itself. When we speak of a symbol representing a variable number, we know that, though we say the symbol changes its values, it is we ourselves who arbitrarily change the meaning of the symbol. We can imagine (waving all question about the possibility of our imagination, or its metaphysical truth) everything annihilated except two material points, one or both of which are in motion with respect to the other: but we cannot in such a case imagine x to be a symbol of a variable number. Unless some intellect be in existence to mean something by x, or to make a symbol of x, there can be no such thing as a variable number, or as the abstract idea of number at all. When we say, let x be a variable number, we must always be understood to mean, let x be a symbol which at one time we may be allowed to make to stand for one number, and at another time for another.

Now as to *gradual* variation. A point never changes its distance from another by, say a foot, without making every assignable lesser change in the interval. Or, a line which is lengthened from A B to A C by the motion of a point, must at some period of the change be equal to A D, if A D be anything between A B and A C. At least it is a necessary condition of *our* existence to believe this to be as evident as that two straight lines cannot inclose a space, though [SPACE AND TIME] we believe some would be found to deny it. But in the case of number, we cannot form anything but an approximation to this idea of gradual variation. We can pass from 1 to 2 by successive steps, by millions of millions of steps if we please: that is, h representing a small fraction, we can proceed from 1 to 2 by the steps $1+h$, $1+2h$, $1+3h$, &c., in such manner that we shall not arrive at 2 till a million of million of steps have been made. But this is not gradual variation, such as is in our ideas when we think of a line increasing in length by the recession of one extremity from the other. Nor, if we subdivide our steps ever so far, can we, in counting, cease to make steps; that is, we cannot imagine gradual variation of number. When, therefore, we talk of x standing for a number, which is also to represent the number of units in a variable length, we can only mean that our numerical progression can be made, if we please, by steps so small, that whatever length A D may represent, the linear representatives of some or other of the numerical steps by which we pass from the number in A B to the number in A C, may be made as near to A D as we please. It is, no doubt, in this essential distinction between the ideas involved in the variation of number and in that of magnitude, that the existence of INCOMMENSURABLE quantities takes its rise.

The first steps of the Differential Calculus are often embarrassed by a mode of speaking which appears as if two different symbols were used for the same thing. "Thus," it is said, "let x be a variable, and y a function of that variable, such that y is always $=x^2$. Then let x be changed into $x+h$, in consequence of which y becomes $y+k$; so that $y+k=(x+h)^2$." Now if x be the symbol of the *variable* quantity, which can only mean this, that both before the quantity has changed, and after, it is represented by x, how can it be allowed both to let x, as it were, imply its own variation in its very meaning and yet alter x into $x+h$ to denote that x changes? The truth is that the language is incorrect; it should be as follows:—Let there be two variable quantities, one of which is always the square of the other; let x be the value first given to one of the variables, and y to the other, so that $y=x^2$. Then let a new value $x+h$ be given to the first variable, in consequence of which the second becomes $y+k$, so that $y+k=(x+h)^2$. In fact, x does not represent a variable quantity, but a certain value given to a variable quantity.

VARIABLE STARS. This term has been applied to a class of stars which exhibit variations of brightness when observed from time to time. The branch of astronomy which takes cognisance of such objects is entirely of modern origin. The first star of which the light was found to be variable is a small star in the constellation of the Whale, usually designated in the catalogues of astronomers as *o* Ceti, or omicron Ceti. This star was observed by Daniel Fabricius, on the 13th of August, 1596, and noted by him as a star of the third magnitude. In the month of October of the same year, the star had vanished from observation, as if it had been extinguished, and for some time afterwards it does not seem to have attracted the notice of observers. Bayer, in his 'Uranometria,' published in 1603, has inserted the star, but he makes no allusion to its previous disappearance. The discovery of the variability of its light is due to Holwarda, a Dutch astronomer. In the month of December, 1638, Holwarda perceived the star during an eclipse of the moon, when it exceeded in brightness a star of the third magnitude. About the middle of the following summer he was unable to discover the slightest trace of it. However, on the 7th of November, 1639, he again detected it in its original position.

The star was now carefully observed by several individuals, among the rest, by the famous Hevelius. The discovery of the period of its variations is due to Bouillaud, who found that an interval of 333 days elapsed between two successive disappearances or reappearances. The results of modern observation indicate the exact period to be $331^d\ 15^h\ 7^m$.

In addition to the star to which we have just been referring a great many other stars have been found to be variable, and the number is rapidly increasing every year. This important result is due in a great degree to the practice of carefully scrutinising small stars in connection with the search for asteroids which has been so assiduously prosecuted in recent years by a number of individuals in different countries. We shall now allude briefly to the peculiarities of two or three other examples of variable stars.

β Persei. This star, usually termed Algol, which is situate in the head of Medusa, was found by Montanari and Maraldi to exhibit strange fluctuations of brightness, but the period of its variations was first established by Goodricke in 1782. It generally appears as a star of the second magnitude. In the short space of three hours and a half it descends to the fourth magnitude, and then in an equal interval of time regains its usual brightness. It shines as a star of the second magnitude during the space of two days, thirteen hours, and three-quarters, and it consequently passes through the complete cycle of its changes in two days, twenty hours, and three quarters. According to Argelander, the exact period is $2^d\ 20^h\ 48^m\ 52^s$.

β Lyræ. This star was first found to be variable by Goodricke in 1784. It is an object of great interest, inasmuch as it possesses a double maximum and a double minimum. When it arrives at its maximum brightness, it resembles a star of the third magnitude. At one of its minima it appears between the third and fourth magnitude, and at the other, between the fourth and fifth magnitude. Argelander has found that it passes through its variations in $12^d\ 21^h\ 53^m\ 10^s$.

δ Cephei. This interesting star was also first discovered to be variable by Goodricke in 1784. Argelander determined its period to be $5^d\ 8^h\ 47^m\ 39{\cdot}5^s$; but the late Mr. Johnson, director of the Radcliffe Observatory, Oxford, fixed the period at $5^d\ 6^h\ 42^m\ 18{\cdot}4^s$. At its minimum it is equal to a star of the fifth magnitude, and it hence increases until it resembles a star between the third and fourth magnitude at its maximum. The interval which elapses between the maximum and the minimum is $3^d\ 19^h$, while between the minimum and the maximum the interval is only $1^d\ 14^h$.

Some stars have been discovered to be variable, but their fluctuations are so irregular that it has been hitherto found impossible to reduce them to any fixed law. A remarkable example of this kind is furnished by the bright star in the southern hemisphere, denominated *η* Argûs. In 1677, Halley, during his residence at St. Helena, classed it among the stars of the fourth magnitude. In 1751, Lacaille estimated it to be of the second magnitude; however Burchell, who resided in South Africa from 1811 to 1815, again ranked it among the stars of the second magnitude. From 1822 to 1826, it was estimated to be of the second magnitude by Brisbane and Fallows, who observed it, the former at New South Wales, and the latter at the Cape of Good Hope. In 1827, Burchell, while residing at St Paul's, Brazil, estimated it to be of the first magnitude, and almost equal to *α* Crucis; but in the following year he found from observations made at Goyer, that it had again descended to the second magnitude. Johnson, who observed the star at St. Helena between 1829 and 1833, estimates it to be of the second magnitude; and Taylor's observations at Madras during the same period indicate the same fact. Sir John Herschel also, from the time of his arrival at the Cape of Good Hope in 1834 till 1837, estimated it invariably to be between the first and second magnitude. But on the 16th of December, 1837, while engaged in making photometric observations of the small stars in its vicinity, he was surprised to find that it had rapidly increased in brightness. It was now equal to α Centauri, and far surpassed in brightness all the other fixed stars except Canopus and Sirius. It attained its maximum brightness on the 2nd of January, 1838. Shortly afterwards it grew fainter, and it continued to diminish in brightness till March, 1843. In the following month it again rapidly increased in brightness. According to the observations of Maclear at the Cape of Good Hope, and of Mackay at Calcutta, it now surpassed Canopus in brightness, and almost rivalled Sirius. It continued for several years to exhibit this great degree of brightness, when it began to fluctuate as before.

The new stars which have appeared in the heavens, and of which several instances are recorded in history, probably belong to the class of variable stars. The most notable objects of this description are the new star which appeared in 1572, of which Tycho Brahe has given a detailed account, and the new star of 1604, which was observed by Galileo and Kepler.

The following table of variable stars, drawn up by Mr. Pogson, is extracted from vol. xvii. of the 'Observations made at the Radcliffe Observatory,' Oxford. Mr. Pogson is known as one of the most successful explorers of this interesting field of astronomy.

Name.	Discoverer of Variability.	Observed Variation of Magnitude.		Elements.		Authority.
		Max.	Min.	Epoch.	Period.	
α Cassiopeiæ	Birt	2·0	2·5	Uncertain	79·1 days	Argelander.
ο Ceti	Holwarda	2·0	Under 12	1861, June 16·45	331·3363 days	Argelander.
β Persei	Montanari	2·3	4·0	†1854, Oct. 8·22355	2·86727 days	Argelander.
λ Tauri	Baxendell	4·0	4·5	†1858, June 2·633	3·953 days	Baxendell.
R Tauri	Hind	8·0	Under 13·5	1856, Feb. 2	330 days	Winnecke.
ε Aurigæ	Heis	3·5	4·5	Uncertain	Unknown	
R Leporis	Schmidt	7	..	Uncertain	Unknown	
α Orionis	Herschel	1	1·5	1852, Nov. 26	196 days	
ζ Geminorum	Schmidt	3·8	4·5	†1857, Feb. 7·3000	10·15833 days	Argelander.
R Geminorum	Hind	7	11	1848, Nov. 14·5	369·73 days	Pogson.
S Can. Min.	Hind	8·5	..	1856, Dec. 10	335 days	Schönfeld.
S Geminorum	Hind	9	Under 13·5	1848, Feb. 20·1	294·07 days	Pogson.
T Geminorum	Hind	9	Under 13·5	1848, Feb. 22·8	288·62 days	Pogson.
R Cancri	Schwerd	6	Under 10	1857, Feb. 23	380 days	Argelander.
S Cancri	Hind	8	10·5	†1854, June 22·4714	9·48397 days	Argelander.
S Hydræ	Hind	8·5	13·5	1857, Feb. 20	256 days	Schönfeld.
T Cancri	Hind	9·5	12	Uncertain	Unknown	
R Leonis	Kock	5	10	1854, Nov. 27	312·17 days	Pogson.
R Urs. Maj.	Pogson	7	13	1853, March 24·1	301·90 days	Pogson.
R Virginis	Harding	6·5	Under 11	1856, Jan. 13·97	145·724 days	Argelander.
S Urs. Maj.	Pogson	7	12	1853, Aug. 23·3	222·65 days	Pogson.
S Virginis	Hind	5·5	11	1854, Feb. 7·5	380·11 days	Pogson.
S Serpentis	Harding	8	Under 10	1857, April 5	367 days	Argelander.
R Cor. Bor.	Pigott	6	..	1854, June 15	323 days	Argelander.
α Herculis	Herschel	3	3·5	1856, May 18	66·33 days	Argelander.
R Scuti	Pigott	5	9	1857, Nov. 23	71·75 days	Argelander.
β Lyræ	Goodricke	3·4	4·3	†1857, Feb. 6·0792	12·90639 days	Argelander.
R Aquilæ	Argelander	6·5	..	1857, July 20	351·5 days	Argelander.
R Cygni	Pogson	7·5	Under 14	1852, Aug. 7·5	416·72 days	Pogson.
η Aquilæ	Pigott	3·6	4·4	1857, Feb. 6·6056	7·17631 days	Argelander.
34 Cygni	Janson	3	Under 6	Uncertain	18 years	Pigott.
24 Ceph. (Hers.)	Pogson	5	11	1807	73 years	Pogson.
S Capricorni	Hind	9	11	Uncertain	Unknown	
T Capricorni	Hind	9	Under 14	1855, Oct. 25	274 days	Schönfeld.
μ Cephei	Herschel	3	6	1857, April or May	Unpublished.	Argelander.
δ Cephei	Goodricke	3·7	4·8	†1857, Feb. 6·0516	5·366436 days	Argelander.
β Pegasi	Schmidt	2	2·5	Uncertain	41 days	Schmidt.
R Cassiopeiæ	Pogson	6·0	Under 14	1853, April 28·9	434·81 days	Pogson.

The epochs marked thus † are epochs of minimum.

No satisfactory explanation of the phenomena of variable stars has hitherto been advanced by any inquirer. Some astronomers have suggested that the variations of light may be due to dark bodies circulating around the stars. According to others, the fluctuations of brightness may arise from the presence of dark tracts on the surfaces of the stars, which are periodically turned towards the earth by the revolution of the stars on their axes. The phenomena, however, are in general so irregular, that neither of these hypotheses is capable of satisfactorily accounting for them.

VARIATION. Under this head comes the explanation of a part of the language of proportion which is much used, and which was once very prominent in English mathematical writings. We refer to such phrases as the following:—A varies as B—A varies inversely as B—the gravitation of particles varies inversely as the squares of their distances—the time of oscillation of a pendulum varies as the square root of its length, &c.

When we say that one thing varies as another, we mean that there are two variable magnitudes which have this property, that if when the first changes from A to B the second change from a to b, then A is to B in the same proportion as a to b. And when we say that one thing varies inversely as another, we mean that if when the first changes from A to B the second changes from a to b, then—

$$A : B :: \frac{1}{a} : \frac{1}{b} \text{ or } :: b : a.$$

The modes of denoting these laws of connection used to be, in English works—

$$A \propto a \qquad\qquad A \propto \frac{1}{a}.$$

These were in fact but modes of writing the equations

$$A = c\,a \qquad\qquad A = \frac{c}{a}$$

in a manner which should recognise their existence without obliging us to think of the particular value of the constant c. According to the preceding equations, if we take the first, and suppose that A changes into B when a changes into b, we see obviously that $A \div B$ is the same as $a \div b$, both being equal to c. And $A \propto a$ informs us that $A \div a$ is always the same quantity, without saying what it is.

When one quantity varies as both of two others jointly, it means that if either of the second and third mentioned remain constant, the first varies as the other. Thus the price of a quantity of goods varies jointly as the number of things and the price of each. At a given price per article, the whole price varies as the number of things; for a given number of things, the whole price varies as the price of one. When x varies as y and z jointly, the equation $x = c\,y\,z$ is implied.

We are rather inclined to regret the complete disappearance of the *notation* of variations which has taken place within the last thirty years, though the *phraseology* is still in some degree of use. It is now usual either to write equations at full length, or to make an equation of the variation itself, which can always be done by a proper choice of units. Thus $A \propto a$, or $A = c\,a$, can always be made $A = a$, if such choice of units be made in which to measure the magnitudes A and a as will make $c = 1$. This must be done by contriving that A and a shall become unity together. But this, however convenient for mere calculation, is likely enough to produce confusion in the mind of the learner, and actually does so in many instances. It is obvious enough that of two different kinds of magnitude one may *vary* as the other:

thus the height of the barometer (a length) varies as the pressure of the atmosphere on a given surface (a weight). But it is just as obvious that one magnitude cannot be *equal* to another, unless the two be of the same kind. When therefore a writer on mechanics, with little or no previous explanation about the units employed, states that the *weight* of a body is its *mass* multiplied by the *force* of gravity, or that the *pressure* on a mass is equal to the *mass* multiplied by its *acceleration*, he writes effectively only for a reader who knows the subject already. The weight of a body varies jointly as its mass and the acceleration which the force of gravity would create in one second. Alter either of these alone, and the weight is altered in the same proportion. Hence, if w, m, g be the numbers of units of their several kinds in the weight, the mass, and the acceleration caused by gravity, the equation $w = cmg$ must subsist, where c is a numerical constant depending on the units employed. If the weight which is called 10 (pounds, ounces, or whatever they may be) belong to the mass called 5, when acted on by such gravity as produces an acceleration of 4 (feet, yards, or whatever the unit of length may be) in the time called 1 (second, minute, or other unit of time), then $10 = c \times 5 \times 4$, or $c = \frac{1}{2}$. So long as the same units of length, time, mass, and weight are employed, the equation $w = \frac{1}{2} mg$ must subsist: change the units, and the constant c must have another value, to be again determined from an instance. When the writer above mentioned says that $w = mg$, he means, or ought to mean, that it is an agreement between him and his reader that whatever mass may be called 1, and whatever may be meant by 1 of length and 1 of time, the weight which is called 1 shall be that of the mass 1 acted on by the force of gravity 1. The older writers, who used variations, needed no specifications of this kind, since the actual concretes themselves were the subjects of reasoning, and the variation asserted was true both of the concrete magnitudes and of any system of units which they might adopt. The introduction of their units was naturally and easily made; and when variations became equations, the student could not help seeing the introduction of all conditions depending on the mode of measurement. In dropping the notation of variations, our writers passed into that want of distinct explanations of primary terms which was the characteristic of many of the French writers.

The beginner must carefully bear in mind that one quantity does not vary *as* another, because it varies *with* that other. A square and its root vary together, but the square does not vary *as* its root: if, for instance, the root be doubled, the square is not doubled, but quadrupled.

It is however most important to remember that when two quantities change together, in any manner whatsoever, the increment of the one varies as the increment of the other very nearly, if both the increments be small, and the more nearly the smaller they are. Thus, if we know that when x has a certain value, the addition of $\cdot 01$ to x gives an addition of $\cdot 001$ to its logarithm, we may be sure that the addition of $\cdot 01 \times h$ to x will give an addition of $\cdot 001 \times h$ to the logarithm, very nearly, as long as $\cdot 01 \times h$ is small.

VARIATION OF THE COMPASS. [COMPASS CORRECTION; DECLINATION; MAGNET; TERRESTRIAL MAGNETISM.]

VARIATION OF THE MOON. [MOON.]

VARIATION OF PARAMETERS. A *parameter* was a name originally given to a particular line connected with a conic section: being the third proportional to a diameter and its conjugate. In time the word was applied to any line which serves by its value to distinguish, or to help to distinguish, one individual of a family of curves from another: thus the radius of a circle, the axes of an ellipse, the co-ordinates of the centre of either, were called parameters. When a word gets into the descriptive name of a method, it may happen, as part of a phrase, to outlive its own separate use; and such has been the case with the word *parameter*. As this word is now generally abandoned, *element* is the most frequent substitute for it, and it would be desirable to speak of *variation of elements*.

Whatever phrase we may use, the thing occurs both in physics and mathematics, in modes which are closely connected with each other. A planet moves in a curve which is not an ellipse, but which would change and become an ellipse if the disturbing attractions of the other planets were removed, and that of the sun only continued. The easiest way of calculating the planetary motions is to consider the planet as moving in this ellipse, while during the motion the elements which determine the ellipse are perpetually changing; so that the form and position of the ellipse both vary. This is done in such manner that the ellipse of each moment is that which the planet would go on to move in, if at that moment the disturbing attractions were all removed. The advantage is that in this case the elements will vary very slowly, or it will be long before the disturbing attractions produce much effect. In theory, any curve might be taken. A planet for instance might be supposed to move in a parabola, which varies its dimensions and position in a manner to be determined. In TROCHOIDAL CURVES, all the curves given are produced by a point moving in a circle with variable elements; that is, of variable centre, though given radius. If it were required to investigate trochoidal curves with loops and undulations of different magnitudes, the best way would be to consider them as made in the same manner, with a circle of variable radius also: or else to make both circles variable.

In the differential calculus the variation of elements is introduced thus:—If an algebraical expression containing some variables and some constant elements be proper to answer a certain purpose, it is not impossible that it may answer the same purpose when the constants are made variable, provided they be made to vary in a proper manner. Now, if the purpose which is to be answered involve differentiation, the infinity of the number of suppositions which may be made as to the variation of the (former) constants is equivalent to introducing an arbitrary function instead of each constant, to be determined by the conditions of the question. Two species of cases have frequently arisen.

1. When under certain circumstances a problem is solved by an expression containing certain constants, and the circumstances are then altered; it is often convenient to inquire whether the altered problem might not be solved by the same expression, on the supposition that the constants become variable. And the question then is, how the (former) constants are to be made to vary.

2. Without any alteration of the circumstances, having a solution which contains constants, it may be asked how to substitute variables in place of constants, so that the altered expression may still be a solution.

In both cases it is obvious that so soon as the constants are made variable the differential co-efficients of all expressions into which they enter will receive an accession of terms above what they had before. These new terms, which we may describe as functions of the variations of the elements, must, in the first case above noted, be so taken as to provide for the effect of the altered circumstances. But in the second case they must destroy one another's effects altogether. We shall take a few instances in which the variation of elements is successful or unsuccessful.

1. The equation $y' + \mathrm{P}y = 0$, P being a function of x, is solved by

$$y = \mathrm{C}\epsilon^{-\int \mathrm{P}dx}$$

C being a constant. Now alter the equation into $y' + \mathrm{P}y = \mathrm{Q}$, and to meet the alteration, let C become a function of x. On this supposition $y' + \mathrm{P}y$ becomes

$$-\mathrm{CP}\epsilon^{-\int \mathrm{P}dx} + \mathrm{C}'\epsilon^{-\int \mathrm{P}dx} + \mathrm{CP}\epsilon^{\int \mathrm{P}dx}$$

But this ought to be Q: therefore we must have

$$\mathrm{C}'\epsilon^{-\int \mathrm{P}dx} = \mathrm{Q}, \quad \text{or } \mathrm{C} = \int(\mathrm{Q}\epsilon^{-\int \mathrm{P}dx}) + \mathrm{E}$$

E being another constant. Here $y' + \mathrm{P}y = \mathrm{Q}$ is solved by $y' + \mathrm{P}y = 0$ and subsequent variation of an element.

Now try $y' + y^2 = 0$ and $y' + y^2 = \mathrm{Q}$ in the same manner. The first is solved by $y = (x + \mathrm{C})^{-1}$ and if C be made variable, and y thus altered be introduced into the second, it is found, making $z = x + \mathrm{C}$, to require the solution of

$$z' + \mathrm{Q}z^2 - 1 = 0$$

as difficult an equation as the original. In this case then we are unsuccessful.

2. Let $\frac{du}{dx} + \frac{du}{dy} = x$. One solution of this is $u = \frac{1}{2}x^2 + a(x-y) + b$, a and b being constants. To find a more general solution of this same equation let b be a function of a, a being a function of x and y. We have then

$$\frac{du}{dx} = x + a + \left(x - y + \frac{db}{da}\right)\frac{da}{dx}$$
$$\frac{du}{dy} = -a + \left(x - y + \frac{db}{da}\right)\frac{da}{dy}$$

and the equation will obviously still be satisfied if b and a be so related that

$$x - y + \frac{db}{da} = 0$$

Now as b is what function of a we please, so also is $\frac{db}{da}$: hence it follows that if $b = \phi a$, and $x - y = -\phi' a$, we may make a what function of $x - y$ we please. Let $a = \psi(x-y)$ and let $\chi v = \int v\psi' v\,dv$. We have then

$$u = \frac{1}{2}x^2 + (x-y)\psi(x-y) + \chi(x-y)$$

of which the last two terms merely amount to an arbitrary function of $x - y$, so that the complete solution is

$$u = \frac{1}{2}x^2 + \phi(x-y)$$

ϕ meaning any function whatever.

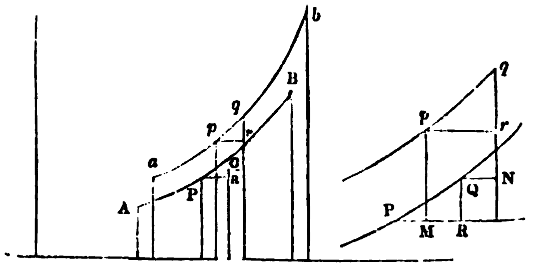
This subject has many developments. We have introduced it here under the idea that some students of the differential calculus may be led to consider it at an earlier period of their reading than books will give it to them.

It is to be remarked that this method does not merely search for *some* solutions of a question: if the number of constants be sufficient, it goes direct to the most general solution. In our first example there is no function of x but what is capable of being represented by

$C\epsilon^{-\int P dx}$; in our third there is no function of x and y but what is capable of being represented even by $\frac{1}{2}x^2+a(x-y)$ or $\frac{1}{2}x^2+b$, and also by $\frac{1}{2}x^2+a(x-y)+b$ with a relation between a and b. Whatever function of x, or of x and y, will solve these equations, is sure to be found, if the method be successful. This point would need a little more development than we have here space to give.

VARIATIONS, CALCULUS OF. The preceding words might seem fit to include every organised mode of dealing with the variations of value which algebraical quantities are made to receive; the differential calculus, for example: but they have a technical meaning, which we proceed to explain. When a quantity is subject to one sort of variation only, the consideration of that variation belongs to the simple differential calculus: but when it is subject to two or more distinct sorts of variation, suppose that of the differential calculus and another, then the mode of dealing with the second sort of variation is said to belong to the calculus of variations. In dynamics, for example [VIRTUAL VELOCITIES], there are two distinct species of motion to consider: one which, at the end of the time t, the system is about to take during the ensuing time dt, in consequence of the velocities acquired by its particles; and another which, without any consideration of the first, must be impressed upon it for the examination of the conditions which express the equivalence of the impressed and effective forces. Here then is a case for the calculus of variations.

Suppose a curve A B, with which is connected another, ab, infinitely near to the first, and related to it by a given law, in such manner that any point P being given on the first, a corresponding point p can be found on the second. If the coordinates of P be x and y, and those of Q (infinitely near to P) be $x+dx$ and $y+dy$, and if we signify the coordinates of p by $x+\delta x$ and $y+\delta y$, we have two distinct notations, one for the increments which the coordinates receive in passing from point to point on the first curve, the other for those which they receive in passing from a point on the first curve to the corresponding point on the second. Hence, P R being dx, and pr what dx becomes after *variation*, we have $\delta(dx)=pr-$ P R which is obviously equal to Q N—P M.



But P M is δx, and Q N is what δx becomes when x is changed into $x+dx$, whence Q N$-$P M$=d(\delta x)$; or $\delta dx=d\delta x$, and the same may be proved for y. We shall now recapitulate the results of the further application of this method. It is quite beyond our limits to attempt to prove them; so that, referring to works on the differential calculus for further information, we shall content ourselves with some remarks on the loose manner in which this calculus is nearly always applied to questions of maxima and minima, and to a very few words on its history.

1. The operations of differentiation and variation are interchangeable in order, as in $\delta dx=d\delta x$, $\delta\int \text{v}dx=\int\delta(\text{v}dx)$, &c.

2. If y be a function of x, and if y', y'', &c., stand for successive differential coefficients of y with respect to x, the successive differential coefficients of $\delta y-y'\,\delta x$ are $\delta y'-y''\delta x$, $\delta y''-y'''\delta x$, $\delta y'''-y^{\text{iv}}\delta x$, &c.

3. Let V be a function of x, y, y', y'', &c., and let $\int \text{v}dx$ taken from $x=x_0$ to $x=x_1$ be required, and let y_0, y'_0, y''_0, &c., and y_1, y'_1, y''_1, &c., be the values of y, y', y'', &c., when $x=x_0$ and $x=x_1$: and let moreover $\omega=\delta y-y'\delta x$, which becomes ω_0 and ω_1 at the two limits. Let the differential coefficients of V with respect to x, y, y', y'', &c., separately made variable, be X, Y, P, Q, &c., and let the complete differentiations of these with respect to x be denoted by accentuations, and their limiting values by subscript ciphers and units as before: then we shall have for $\delta\int\text{v}dx$ the following formula:—

$$\begin{aligned}
&\text{V}_1\,\delta x_1-\text{V}_0\delta x_0\\
&+(\text{P}_1-\text{Q}'_1+\text{R}''_1-\&\text{c.})\,\omega_1-(\text{P}_0-\text{Q}'_0+\text{R}''_0-\&\text{c.})\,\omega_0\\
&+(\text{Q}_1-\text{R}'_1+\text{S}''_1-\&\text{c.})\,\omega'_1-(\text{Q}_0-\text{R}'_0+\text{S}''_0-\&\text{c.})\,\omega'_0\\
&+(\text{R}_1-\text{S}'_1+\text{T}''_1-\&\text{c.})\,\omega''_1-(\text{R}_0-\text{S}'_0+\text{T}''_0-\&\text{c.})\,\omega''_0\\
&+\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\\
&+\int_{x_0}^{x_1}(\text{Y}-\text{P}'+\text{Q}''-\text{R}'''+\&\text{c.})\,\omega dx.
\end{aligned}$$

The most usual application of the preceding formula, in its most general geometrical form, is as follows:—V being a given function of x, y, y', &c., it is required to draw a curve such that $\int\text{v}dx$ shall be the greatest possible or the least possible, provided that at one limit of integration x_0 and y_0 shall be coordinates of one given curve, and that at the other limit x_1 and y_1 shall be coordinates of another given curve. Such a case arises when it is required to draw the shortest line between two given curves, or to find in what form and position a flexible curve of given length will rest when its ends are supposed to slide upon given curves. We have pointed out (Differential Calculus, 'Library of Useful Knowledge,' ch. xvi.) that the ordinary mode of treating these questions is not sufficiently general, and must in certain cases even lead to positive error. We intend here to enforce this conclusion by showing that even in more ordinary questions of maxima and minima the same want of generality may lead to the same sort of false conclusion.

A maximum, or greatest value, means one which is greater than any neighbouring value; so that when a function is at its maximum, any allowable slight change must be one of diminution. For greater read less, and for diminution increase, and we have the definition of a minimum. Now an ordinary question of maxima and minima is as follows:—ϕx being a function of x, what are the real values of x which make it a maximum or minimum? There is a maximum when $x=a$, provided that $\phi(a+h)$ and $\phi(a-h)$, when both are possible, are both less than ϕa: but if one of the two $\phi(a+h)$ and $\phi(a-h)$ be impossible, there is a maximum if *both values* of the other be less than ϕa. In all these cases it is supposed that h may be as small as we please. Now—

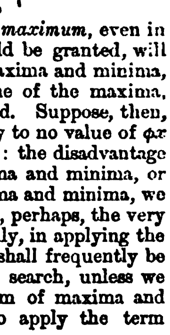
1. When $\phi(a+h)$ and $\phi(a-h)$ are both real, the theory explained in MAXIMA AND MINIMA is perfectly sufficient: there is a maximum when $\phi' x$ changes from positive to negative in passing through $\phi' a$, and there is not a maximum in any other case.

2. When $\phi(a+h)$ is impossible, there is a maximum if both values of $\phi' x$ be positive from $x=a-h$ up to $x=a$: when $\phi(a-h)$ is impossible, there is a maximum if both values of $\phi' x$ be negative from $x=a$ to $x=a+h$.

It is the neglect of the second case which has led to the oversight in the calculus of variations which we shall presently mention. We shall now propose a case as follows:—It is required to find the maximum value of y in the equation

$$y=(1-x)^{\frac{3}{2}}+x^{\frac{3}{2}}=\phi\, x.$$

The form of the curve which has this equation is as in this diagram; O being the origin and O A (= A P) being unity. Now it ought certainly to be said that A P is the greatest ordinate of the curve, but neither is $\phi' x$ here equal to nothing, nor does it change sign. In fact when $x=1$, we have $\phi\, x=1$, $\phi' x=1{\cdot}5$. The second criterion shows that A P is a maximum; the first shows nothing of the kind.

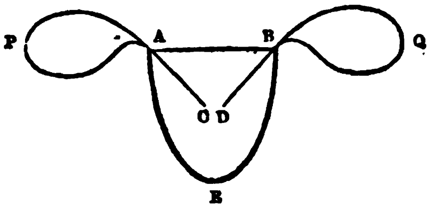


Now we can easily imagine it said, that in such a case as the preceding, A P, though unquestionably the greatest ordinate the curve can have, is not what is technically called a maximum: but it is meant that the last term should be restricted solely to denote those values of ϕx in which $\phi(x+h)$ and $\phi(x-h)$ are *both possible*, and both less than ϕx. To this, *ceteris paribus*, there could be no objection: it often happens that the technical use made of a foreign term will not bear, and is not meant to bear, translation into our own language. The word *maximum*, even in its widest allowable use, and if all we ask for should be granted, will not answer to *greatest*: for there may be several maxima and minima, and some of the minima may be greater than some of the maxima, which cannot be true of the words when translated. Suppose, then, that the word maximum is so restricted as to apply to no value of ϕx except when $\phi(x+h)$ and $\phi(x-h)$ are both possible: the disadvantage will be twofold. First, in every problem of maxima and minima, or in every problem which is reducible to one of maxima and minima, we shall have to invent an additional term to signify, perhaps, the very greatest or very least value of the function. Secondly, in applying the same limitation to the calculus of variations we shall frequently be obliged to forego the solution of which we are in search, unless we look for the very case, as an answer to a problem of maxima and minima, to which we have previously refused to apply the term maximum or minimum.

In order to make $\int\text{v}dx$, as before described, a maximum, it is generally presumed that $\delta\int\text{v}dx$ must $=0$, and that y must be found in terms of x from this condition. Now the truth is that $\int\text{v}dx$, after the variation, becomes $\int\text{v}dx+\delta\int\text{v}dx$, and all that is absolutely necessary is that $\delta\int\text{v}dx$ should be always negative, for all values of δx and δy between the limits, and for all values which are consistent with the limiting conditions, at the limits. It is easily shown that this requires, as to the indefinite integral part, the following equation:—

$$\text{Y}-\text{P}'+\text{Q}''-\text{R}'''+\ldots\ldots=0;$$

and if we be resolved not to consider any points of the limiting curves, except those at which δx_0, δx_1, δy_0, δy_1, may be either positive or negative, as we please, then it is easily proved that the rest of the expression for $\delta\int \mathrm{v}dx$ must also vanish, and this limitation is generally made in works on the subject, by which means solutions are misstated and may even be lost sight of. Thus it is generally asserted that the shortest line between two curves is always a straight line which is perpendicular to the tangents of both; and that a flexible chain, allowed to slide between two curves, with an extremity on each, is in equilibrium when it is in the form of a catenary perpendicular to the retaining curves at the points of suspension. On this we need only direct attention to the accompanying figure. The shortest line that can be drawn between the curves A P A and B Q B is A B, which is perpendicular to neither of the tangents A C, B D; and the flexible chain A E B will hang from the cusps A and B without the slightest tendency to become perpendicular to A C and B D at its extremities.



The fact is, that owing to the very great complexity of the mathematical part of the subject, the part of the calculus of variations which relates to the maxima and minima of integral forms is in a very incomplete state: and it is found impossible to introduce what has been done into elementary works. How long it will be before the mere vanishing of a differential or variation will cease, in elementary works, to be taken as the conclusive evidence of a maximum or minimum, depends on the degree in which mathematics will be studied as a discipline, and not solely as an instrument of physical inquiry.

The history of a large part of the calculus of variations is simply that of dynamics from the time when D'Alembert proposed his celebrated principle (1743). But long before this, the questions of maxima and minima which ultimately came to occupy the greater part of professed works on the calculus of variations, took their rise in the researches of the two Bernoullis, and led to their celebrated quarrel. [BERNOULLI, in BIOG. DIV.] The first problem, namely, to find the curve of shortest descent between two given points, proposed by John Bernoulli, was quickly followed by others of the same kind, proposed by James Bernoulli, in which the curve to be found was required to be of a given length. The prevalence of problems in which this last condition was contained, led to the name of the *Solution of Isoperimetrical* problems, by which the calculus in question was long distinguished. But it must be noted that the first who solved any such problem as has since been referred to the calculus of variations, whatever may have been his method, was Newton, who, in the Scholium to the 34th proposition of his second book, gives, without demonstration, the construction requisite for finding the solid of least resistance. [PRINCIPIA, cols. 739–40.] The subject was successively taken up by Brook Taylor, Euler, Simpson, Emerson, and Maclaurin, the second of whom first gave the general equation which determines the nature of the function required, independently of the limits of integration; and his 'Methodus inveniendi lineas curvas proprietate maximi minimive gaudentes,' published in 1744, being the last of his efforts on this subject which was made before Lagrange came into the field, is an epoch in its history. Lagrange's first change in existing methods was the introduction of the specific symbol δ to stand for the variation of x (which suggested to Euler the name of the *Calculus of Variations*) and of the formation of all that part of $\delta\int \mathrm{v}dx$ which is free from the integral sign. Furnished with such an apparatus, he undertook problems of a much more complicated class than any of his predecessors, and stamped upon the subject the form which it has never since lost, at the same time that he gave it an extension which it cannot be said to have since greatly exceeded. Lagrange's memoirs were contained in the first and fourth volumes of the 'Miscellanea Taurinensia,' published in 1760 and 1778. The 'Mécanique Analytique' of Lagrange (first edition, 1788) must also be regarded as the first work in which the calculus of variations was fully applied to problems of statics and dynamics, in the manner since universally followed. A complete and most excellent history of the rise and progress of the branch of this calculus which treats of the maxima and minima of undetermined integrals is contained in, and forms the substance of, Woodhouse's 'Treatise on Isoperimetrical Problems,' Cambridge, 1810. This work carries on the history to the end of the last century, and is worthily succeeded by Mr. Todhunter's recently published 'History of the Calculus of Variations,' Cambridge, 1861, 8vo, which describes what has been done by the successors of Lagrange down to the present time. Accordingly, there is now no branch of mathematics of which *all* the history is so well written as the calculus of variations. The only complete and separate elementary work on the subject is Jellett's 'Calculus of Variations,' Dublin, 1850, an able, elaborate, and, the subject considered, intelligible work.

VARICELLA, or *Varicella lymphatica*, is the eruptive disease commonly called chicken-pox, and which has been described by different writers under the names of *chrystalli, variolæ, pusillæ, variolæ, spuriæ*, &c. It is almost peculiar to infants and young children; and the eruption appears either without premonitory signs, or after two or three days of slight illness. The eruption commences on the shoulders, neck, and breast: on the scalp and back it is usually abundant, but the face is only slightly affected. It consists of vesicles, about as large as a split-pea, full of transparent fluid, and lenticular, conoid, or globular in their form. They are surrounded by a slight superficial redness, and successive crops of them appear for two or three days, the old vesicles shrivelling up as the new ones are formed. Most of the vesicles burst naturally, and the cuticle which covered them falls to the level of the surrounding skin; but some shrink, the fluid within them becoming whey-like, or, if they be much irritated, purulent. After drying they form small scabs, which fall off in grains, and sometimes leave small superficial scars. The whole course of the disease occupies about a week, and is not attended by any important constitutional disturbance. It therefore requires no particular treatment.

The first writers on varicella considered it as only a mild form of variola, or small-pox, and the same view is maintained by some modern authors, especially by Dr. Thomson of Edinburgh. It is however more probable that chicken-pox and small-pox are essentially different, on these grounds: 1. They sometimes prevail in distinct epidemics, no case of genuine small-pox occurring among many of chicken-pox. 2. The characters of the chicken-pox eruption are altogether different from those of small-pox, even in its mildest and most modified form. 3. Chicken-pox is not inoculable, though the mildest small-pox is. 4. Chicken-pox is altogether unaffected by previous vaccination, and does not prevent the action of vaccine matter.

VARICOSE VEINS. [VEINS, DISEASES OF THE.]

VARIOLA. [SMALL POX.]

VARIOLARIN. A substance extracted from lichens. It is supposed to be identical with LECANORIC ACID.

VARIX. [VEINS, DISEASES OF THE.]

VARNISH, a fluid applied to the surfaces of various articles, as wood, &c., and which, by the evaporation or chemical change of a portion, leaves upon them a shining coating, impervious to air and to moisture.

Varnishes may be divided into three classes: alcoholic or spirit varnishes, volatile-oil varnishes, and fixed-oil varnishes.

Spirit or *alcoholic* varnishes are in general prepared very readily, are easily applied, soon become dry, and emit no disagreeable smell: they are, however, liable to crack or scale off, and are incapable of resisting friction or blows. One kind is made as follows:—Mastic 6 ounces, sandarac 3 ounces, reduced to fine powder, and 4 ounces of coarsely-powdered glass; digest in a quart of spirit of wine, contained in a loosely-corked vessel, for three days in a warm room, shaking the mixture frequently; then add 3 ounces of melted Venice turpentine to the warm solution, stirring thoroughly till mixed; let the mixture remain in a warm room for about a week, and then strain it. This is a strong varnish applied to chairs and other articles of furniture. Another consists of copal, which has been liquefied and afterwards very finely powdered, 3 ounces, mastic 2 ounces, and elemi 1 ounce; digest in a warm room in a quart of spirit, and when the solution is complete add 2 ounces of Venice turpentine. This is stated to form a good varnish for violins and other musical instruments. For different purposes the ingredients of spirit-varnishes are considerably varied; seed-lac, benzoin, anime, frankincense, entering into the composition, according to the use to be made of them.

The only *essential* or *volatile oil* largely used in varnishes is oil, or, as it is commonly called, spirit of turpentine; and one of the best varnishes into the composition of which it enters is copal varnish. [COPAL VARNISH.] This is chiefly used for pictures. Another powerful varnish is prepared by adding to highly-rectified oil of turpentine about an eighth of its weight of caoutchouc; this, indeed, is the varnish now generally employed in waterproofing the garments well known by the name of Mackintoshes; sometimes gas-oil, or coal-naphtha, is employed for the same purpose, but its smell is more disagreeable, and longer in going off. The preparation of this varnish does not require the application of heat.

In *fat* or *fixed-oil* varnishes, the solvent undergoes a chemical change, and dries with the substance dissolved: these are sometimes termed fat varnishes. We shall mention two kinds, first the most colourless: this is prepared by mixing 4 ounces of copal, which has been liquefied and finely powdered, with oil of turpentine and drying linseed-oil, of each 10 ounces; digest in a gentle heat till the whole is dissolved; strain it after standing a few days. This forms a solid and nearly colourless glazing, and dries easily at common temperatures. The black varnish used by coachmakers is thus prepared: take of amber 16 ounces, melt it, and add to it half a pint of drying linseed-oil boiling-hot, 3 ounces each of asphalt and rosin, both in fine powder; stir the materials together till they are thoroughly melted and incorporated, add to the mixture a pint of warm oil of turpentine: this varnish is intended to dry to a very hard consistence.

Dr. Cattell, in 1860, proposed to manufacture varnish by dissolving gums in two kinds of liquids, ethylated and methylated. The gums are of the usual kinds; but the varnishes are grouped in one or other of two classes, according to the class of solvent employed. Alcohol, wood spirit, methylated spirit, peat oil, shale oil, benzole, and coal naphtha, are among the solvents named. Various proportions are named between the ingredients, according to the kind of varnish intended to be produced. We may here mention that Mr. Cooley describes no less than sixty-four kinds of varnish, of which the chief are placed under the headings of amber, balloon, black, body, bookbinders', carriage, Chinese, copal, crystal, drying, Dutch, etching, flexible, furniture, glass, gun-barrel, hair, india-rubber, Italian, Japan, lac, mahogany, mastic, oak, oil, leather, picture, printers', spirit, toy, transfer, turpentine, and wax varnish.

Two special kinds of varnish are connected with the processes of *French polishing* and *lacquering*.

French polishing depends on the use of a varnish which, from the ingredients in its composition, admits of being rubbed until great smoothness and gloss are produced. The best French polish is made of pale shellac and rectified spirits of wine; in the next best quality, wood-naphtha is substituted for the spirits of wine. Sometimes mastic, gum elemi, or gum sandarac are used instead of shellac; and a little linseed-oil or copal is mixed with the spirit. When intended to modify the colour of the wood to which the French polish is to be applied, small proportions of other ingredients are added, such as dragon's blood, alkanet root, red sandalwood, turmeric, gamboge, &c. French polish is never required to be so limpid as other varnishes. When an article of wood is to be French polished, the surface is brought to a very smooth and clean state. A rubber is made by rolling up a strip of thick woollen cloth, and using the soft elastic edge of the coil. The rubber, being wetted with the French polish, is inclosed in a doubled cloth of soft linen, the outer surface of which is slightly touched with a drop of raw linseed-oil, and the workman rubs it steadily over the wood, until the rubber and linen become nearly dry. He supplies a second time, and again a third, and perhaps a fourth time, rubbing the wood steadily until each portion of polish is worked in. Very little of the composition is actually laid on; the effect being due rather to skilful manipulation than to a thick layer of glossy material.

Lacquer differs from ordinary varnish and from French polish in being applied either to metal or to hard wood; in other respects lacquers may be regarded as spirit-varnishes. One kind of hard wood lacquer is made in the proportion of 2 lbs. of shellac to 1 gallon of spirit of wine; and another, in that of 1 lb. of seed lac and 1 lb. of white resin to 1 gallon of spirit of wine. Among many kinds of lacquer for metal, one consists of 1 lb. of the best pale shellac to 2 gallons of spirit of wine. Hard wood lacquer is mostly used for turned work: it is applied on a wad or rag while the turned article is rotating, with a few drops of linseed-oil to enable it to work smoothly. For flat woodwork, lacquer is applied much in the same way as ordinary spirit-varnish, with camel-hair brushes. Lacquer for metals differs somewhat in its composition from that for wood. The metal, when about to be lacquered, is cleaned from all grease and oil, then heated to about 200° Fahr., at a lacquering stove, or on a plate heated by gas, or over a charcoal fire, or on a red-hot piece of iron, or on a vessel of boiling water or steam; this heating is necessary to enable the lacquer to attach itself firmly to the metal, and to make the spirit evaporate quickly. The lacquer, which is sometimes coloured to give it a rich tint, is applied with a brush.

VARNISH-TREES. This name has been applied to several trees which exude liquid resins naturally or from incisions. These become dry in the air, and are employed for preserving various articles from the influence of the air, water, or insects, as well as for giving them greater brilliancy, and also for varnishing pictures. Most of them are found in India, Burma, and China. Some of these exude an acrid resinous juice, which on drying becomes black, and is used as a varnish, as that of the *Anacardium occidentale*, or cashew-nut tree. The marking-nut, or *Semecarpus anacardium*, has its outer coat covered with cells filled with a similar black, oily-looking, acrid juice, which is much used as a marking-ink. *Augia sinensis* of Loureiro is said to produce the genuine Chinese varnish with which the different fancy articles are lacquered, and which is black when simply dried, but becomes coloured by the admixture of different pigments. The Japan varnish of Kæmpfer and Thunberg is *Rhus vernix*, and that of the Malayan islands *Stagmaria verniciflua*. Dr. Buchanan informs us that the juice of *Holigarna longifolia* is used in Malabar for varnishing shields. The varnish-tree of the Burmese is described under MELANORRHŒA, in NAT. HIST. DIV. A very fine liquid varnish is also yielded by *Vateria indica* and *V. lanceæfolia*.

VASES, derived from the Latin *vas*, analogous to the German *fass*, a word in its widest sense comprising all vessels intended to contain fluids or other substances, and made of various materials. In ancient art the term is applied to all ancient vessels, but in modern it is limited to those used for ornament. The shapes of vases are various, from a cup or saucer to that called vase or urn in the narrower sense of the word. Those of ancient nations are distinguished by their shape, form, and material, and may be classed into vases destined to hold and preserve fluids or other substances, comprising craters, jars, and bowls; jugs and cruets for pouring out liquids, and cups for drinking. In Egypt, from the scenes represented in the tombs and temples, elegant large vases of the precious metals inlaid with lapis-lazuli or enamel, and chased with figures of animals or flowers, seem to have been manufactured; and also by the neighbouring nations of Asia, subdued by the arms of Egypt. Of similar forms were vessels of bronze, used for culinary and other purposes. Serpentine basalt and aragonite, or oriental alabaster, especially the latter, were favourite materials, and enamelled fayence, or porcelain, principally of blue colour, and opaque glass, were used for smaller vases for the toilet. Pottery was employed for all purposes. Peculiar vases, popularly called *canopi*, were used for holding the viscera of the dead. The forms of Egyptian vases are simple, the prevalent being the oval and expanding lotus shape; the decorations are plain and the ornaments few. The Assyrian vases resemble in their form the Egyptian, but are sometimes ornamented with relief subjects. There are no vases of the other oriental races of antiquity, and although Sidon, in the days of Homer, was famous for its silver vases, no specimens have survived time or destruction. Alabaster vases are, however, known to have been used by the Assyrians and Persians, and have also been found in the early sepulchres of Greece and Etruria. Several remarkable vases of alabaster exist, inscribed with the names of Persian monarchs in hieroglyphic and cuneiform writing. In Asia, vases were often made of precious stones, as agate and onyx, and one of the kings of Pontus, Mithridates VI., had a collection of 2000. The anthrax, or carbuncle, and chrysoprase, and especially crystal, were often used for vases of small dimensions. Besides the larger vases of marble, principally urns, amphora, cups, lavers, and labra of large size, and enriched with reliefs, were in use during the latter days of Greece and the Roman empire. In the best days of the Athenian commonwealth, large lecythi of Pentelic marble, frequently embellished with sepulchral reliefs, were placed on the graves of the dead.

One of the most remarkable classes of ancient vases was the myrrhine, *myrrhea*, *myrrhina*, the material of which has been a source of controversy since the revival of letters. It is supposed to have been Chinese porcelain by Scaliger, jade by Hager, sardonyx by Le Blond, alabaster, onyx, soapstone, jade, opal, mother of pearl, a kind of amber, meerschaum, or an indurated resin; but the opinion of Rosière and Thiersch, that it was fluor-spar, is most favourably received. The difficulty, however, of reconciling the description of Pliny with the appearance of the substances supposed to be the true myrrhine, does not appear to have been entirely overcome. According to Pliny, it was first brought to Rome from Asia, by Pompey, and exhibited in his triumph, B.C. 62. The countries where it was found were Parthia and Carmania, and it was dug out of the earth like rock crystal, or, according to popular report, baked in Parthian furnaces, and is often mentioned in connection with glass, as if some variety of that material [Schol. ad Lucan; and Oudendorp, t. i. p. 292; vol. ii. v. 380], as semi-transparent, with an opalescent gloss. The most valuable kind had spots changing into purple and white, or into both these colours, and others which were iridescent, while any translucency diminished its value. The material was exceedingly fragile, and perfumed with myrrh, but this was probably owing to the former contents of the vases. The material did not admit of the making of vessels of large size, it rarely being found larger than small plinths, *abaci*, or thicker than goblets. Pompey indeed dedicated to the Capitoline Jupiter small jugs, *capides*, and cups of this substance, which soon after became fashionable and the most precious of all materials, costly cups of it being used by the wealthy, out of which they drank the warmed Falernian wine (Martial, xiv. 113). The value of cups of large size was immense; one of the capacity of 3 sextarii, or 4½ pints, being sold for 70 sestertia, or 565*l.* 6*s.* 1*d.*, and a fragment, in the days of Nero deemed a rarity, although according to the jurists they were not considered gems, *lapilli*; and this emperor gave 10 sestertia, or about 80*l.* 15*s.* for a small jug, *capis*, of this material. Still more precious was the myrrhine bowl, of the value of 300 sestertia, or 24,225*l.*, which T. Petronius destroyed, when on the point of death, in order that it should not fall into the hands of Nero. A kind of false myrrhine, of opaque glass, with blue, yellow, white, and purple bands, was manufactured in later times at Alexandria ('Thiersch ueber die Vasa Myrrhina,' Bayer, Akad. Wissensch., t. i. 4to. 1856, 35, p. 443).

Vases of glass of small dimensions were in very early use: amongst the Egyptians small amphoræ and jugs, and toilet phials of opaque glass, dated, as early as B.C. 1450, in the reign of Thothmes III.; while the earliest known dated specimen of transparent glass is a small dicta found at Nimroud, bearing the name of Sargina, B.C. 711. Various vases, cups, phialæ, and jugs, were in extensive use amongst the Greeks and Romans; and in the middle period of the Empire, Alexandria and Sidon supplied Rome with glass vases, especially the makers Irenæus and Artas of Sidon. To this age are to be referred the celebrated Portland and Auldjo vases in the British Museum, made of transparent deep blue glass, with friezes and arabesques of opaque white, exquisitely polished, produced by cutting down the upper strata of white glass in the manner of a cameo. About the 3rd century, A.D., and later, remarkable glass cups with undercut letters in relief, or pateræ engraven with subjects, appear, the so-called *diatreta*. To this and an earlier period belong the remarkable vases of madrepore glass, chiefly pateræ. At a later age glass vessels were ornamented with gilded subjects at the bottom, enclosed by two layers of glass. Glass vases of a remarkable size and fabric, principally deep cups, are found in the Saxon graves, ornamented with undercut projections at the sides, a rude imitation of the more artistic *diatreta*.

In Greece, from the earliest ages, gold and silver vases were used for sacrificial and other purposes, and they abounded amongst the Hellenic and other races of Asia Minor, the most renowned in early times being those dedicated by Crœsus at Delphi, some the works of the Samian Theodorus. After the conquest of Alexander immense numbers of toreutic works, some inlaid with gems, were common all over Greece; and in two remarkable festivals, one of Ptolemy Philadelphus at Alexandria, the other of Antiochus Epiphanes at Antioch, were exhibited immense numbers of these vases; and great services of plate were possessed by the Græco-Asiatic monarchs, which subsequently became the booty of the Romans, and were exhibited in their triumphs, or plundered by their officers. The most celebrated metal vases were those of Boethus, Mys, and Mentor. A few gold vases exist in the museums of Europe, the most remarkable being the ancient Greek *phiale* from Agrigentum, in the British Museum; and that of the age of Severus, discovered at Rennes, in Bretagne, now in the Bibliothéque Impériale of Paris, and the gold vases at Vienna. Silver vases are less rare, and were more often chased by ancient artists, and many specimens of ancient plate, some found in Britain, are preserved in the different museums of Europe. Silver vases were often used for sacred purposes. Bronze vases are still more common and of larger dimensions, and are generally thin and hammered out in *repoussé* work, or else ornamented with elegant cast reliefs, *emblemata;* or detached ornaments, *crustæ*. Etruria and Magna Græcia were celebrated for bronze vases, and highly ornamented specimens from the sepulchres of Greece and Italy are in the principal museums of Europe. They are principally *craters*, pails for holding wine; *oinochoai*, jugs for pouring it out; *cyathi*, for straining it; and *phialai*, saucers; *arytainai*, ladles; and *kylices*, cups; *aryballi*, oil cruets; *lebetes*, pots for boiling; *podaniptra*, foot-baths. Bronze vases, called *echea*, were also used for sounding-boards in the theatres. Etruria was celebrated for its bronze lamps and candelabra; and Pompeii was full of bronze vessels. Considerable taste was shown by the ancients in their bronze vessels, the lips being often decorated with the ovolo ornament, the handles sometimes in shape of the human form, artistically adapted for the purpose, and generally terminating in animal heads, *prokossoi*, at the mouth, while the place of insertion on the body of the vase was ornamented with mythological subjects, or heads in bas-relief. Subjects in outline were sometimes incised on vases, and a magnificent *lebes* from Capua, in the British Museum, has, in addition to the figures in full relief on the mouth, an incised frieze round the body, representing some of the labours of Hercules. These ornaments were often either modelled by artists of merit, or copied from celebrated works of art. In the 4th and 5th centuries, damascened Roman vases were made; enamelled about the same time. The temples of Greece abounded with presents of these vases, along with tripods, statues, and other objects of bronze. Leaden vases were used by the ancients to hold unguents, perfumes, and collyriums.

The most numerous and remarkable ancient vases are those of baked clay, found in recent years all over Greece, Italy and its isles, the north coast of Africa, and the Crimea, in fact throughout the settlements of Greece. Some of them appear to have held the ashes of the dead, and all were made for use or ornament. These vases are painted with a brown or black silicated glaze, and touched up in parts with flat unglazed colours. They were either made on the wheel or moulded, then dried, the subject or ornamentation traced out with a pointed instrument, the black or brown colour, which is a silicated glaze, filled in with a reed pencil, and the muscles and other details incised through the black colour to the ground of the clay with a sharp knife. Their paste varies from a pale straw to a dark red, and is very soft, light, and porous. The vases appear to have been carefully dried, painted, and baked in close furnaces; the colours used in the decoration being all minerals,—black oxide of manganese and iron being used for the black; oxides of iron, copper, and pipeclay for the other colours. The glaze is a fine silicate of soda, perhaps produced by salt. The style, shape, and ornaments of these vases vary in the different localities where they are found. The earliest of large shape, chiefly jugs, amphoræ, and lekane, found on the most ancient sites of Asia Minor, as at Mount Sipylus and the so-called treasury of Atreus at Mycenæ, are ornamented with friezes, mæanders, zigzags, and such simple ornaments, with animal forms of small proportions introduced as friezes, or metopes. These vases of the heroic period of Greece, probably of the 8th or 9th century B.C., were succeeded by another class, which has been extensively found at Athens, Corinth, Italy, and the Isles, distinguished by friezes of animals of larger size, of black or brown colour, with incised lines upon a pale straw-coloured ground, still accompanied by ornaments, and the area of the friezes are of animals, some with flowers. A few vases of this style have human figures, combats, and myths, derived from Homeric poems, with inscriptions as old or older than the 5th century B.C., their art resembling the oldest sculpture of Selinus and Ægina. By degrees the vase art improved, the potters introducing a slightly warm tone into their clay, abandoning the excessive use of ornament and the flowers in the field, and giving more importance to the human figures, although still retaining friezes of animals. The principal shapes of these vases are the *pelike*, *oinochoai*, and *alabastros*. From the shape of the inscribed letters found upon them, and their art, these vases appear to be as old as the 5th century B.C. The great improvement in style consisted in introducing a warmer tint into the paste of the clay, which became of a light bright red, while the colour of the figures became of a jet black, with the same details as those of the previous classes, and occasional use of white accessories. The vases of the so-called old style are distinguished by their superior art and size, and the interesting mythological subjects with which they are painted, and are often of large size. *Hydriæ*, water vases with three handles, *amphoræ*, two handled jars, *oinochoai* wine jugs, *lecythi*, oil cruets, *crateres*, bowls for holding wine, *cylices*, flat shallow cups, and *cyathi*, cups, occur in this style. The eyes of the figures are painted oblique, the hands and feet long, the forms muscular, the attitudes rigid. The subjects are principally derived from the myth of Bacchus, the Gigantomachia, the Amazonomachia, and the war of Troy. The figures are sometimes explained by accompanying inscriptions. Besides the names of figures, the names of beautiful youths and females, and of the artists who painted and the potters who made the vases, are painted on them, while memoranda relative to the proprietors of the vases are often found incised on the foot.

The style with black figures seems to have flourished till the 4th century B.C. The prize vases given in the Panathenæa having on one side a Pallas Athene and on the other the different games, and inscribed "Prizes from Athens," were of the hard black style, which was conventionally retained till the time of Alexander the Great, the vases being then inscribed with the names of the Athenian archons. But this style of painting was by no means keeping pace with the development of art, and the vase painters towards the close of the 4th century B.C., or even earlier, changed the colour of the figures to a bright orange red, and painted the background entirely black. The inner muscles of the figures were indicated by fine lines of a light brown, the coarser ones by black colour, and the principal accessories were in blue and white. The style considerably improved, but still remained "severe," by which it is known; the principal shapes were *amphoræ*, *oinochoai*, *cylices*, especially the last; inscriptions continued to be used; the names of artists are frequently seen. Henceforth the transitions are no longer those of colour, but of art and drawing. The eyes of figures half a century later are not represented oblique but full eyelashes appear, the limbs are broader, the faces grander, and the influence of the school of Zeuxis in painting begins to show itself; the vases are principally *kalpides*, *amphoræ*, *lecythi*, *aryballos*, and large *craters*, often with columnar handles. The subjects represented contain, in addition to those of the preceding classes, many of the exploits of Perseus and Theseus, and others derived from the Tragedians, especially the Oresteid. But this style, about the time of Alexander, or B.C. 330, began to decline, and in the days of Pyrrhus had passed into the florid style, distinguished by considerable artistic differences. The figures are taller and more elegant in their proportions, their hair curiously fine, and the details minute and numerous, the backgrounds being charged with arabesque and floral ornament. The shapes of the vases too are distinguished by narrow necks, thicker bodies, and taller handles: large *craters*, *amphoræ*, and *calpides* are common. Perspective appears in the drawing; gilding is common amongst the accessories. The inscriptions are sometimes incised, but the vases are often without them. Contemporaneous with these vases were the polychromatic, chiefly *lecythi*, made for sepulchral purposes, although *oinochoai* and *cylices* occur. They all have a *leucoma*, or coating of fine stucco, on which the artist drew the subject in red outline, and subsequently filled in the draperies with opaque colour, or else finely traced the subject in a siennic or bistre-coloured outline. The subjects are chiefly from the Oresteid or other sepulchral sources. There are few inscriptions on any of these vases. Towards 200 years B.C. the art was rapidly declining, and the florid gave way for one far inferior in merit, the figures being often coarsely drawn, androgynous in their character, and overladen with white colour, while the subjects are derived from the Bacchanalia, the low comedy and buffooneries of the Athenian stage. On the last vases of this style the drawing degenerates into a scrawl, and these were succeeded by ornaments in opaque white upon a red ground, and these by others with moulded ornaments. The inscriptions on vases are in different dialects, often incorrect, while the number of inscribed vases is much less than those without. From some memoranda inscribed by the potters upon the vases the prices paid for vases of inferior kinds are known. A *cylix*, or flat painted cup, cost a drachma, which at the different value of money in ancient times amounted to about 3*s*.; a *crater* 4 oboli, or 2*s*.; a *lecythus* 1 obolos, or 6*d*.; a small pot ½ an obolos, or 3*d*.; and a saucer ⅓ obolos, or 2*d*. It is curious to contrast this with the sums paid for valuable ancient vases in modern times. The Durand collection alone, principally vases, realised 12,524*l*.; in 1836 a vase, with the subject of the death of Orestes, sold for 264*l*.; and other important vases for as much as 280*l*., 240*l*., and 170*l*. each. Yet, these sums are far inferior to those paid for remarkable vases by the Naples Museum, a vase with the last night of Troy having been acquired for 1000*l*., and the same sum was paid by the late Mr. Edwards for a large vase, now in England. The characteristics of Etruscan and Roman vases have been already mentioned. [POTTERY.]

One of the most difficult portions of the history of vases has been their nomenclature, obscured by the difficulty amongst the ancients themselves of describing or defining vases, and the various names in use at different periods. The names of vases have been classed under their employment, as the *pithos, stamnos, bikos, hyrche, lagynos, pytine, askos, oinophoros, amphoreus, kados, hydria, kalpis, krossos*, for containing liquor; the *kothon* and *rhyton, bessa, bombylios*, for wine; the *lecythus, olpe, alabastros*, for oil; the *crater, psycter*, and *dinos*, for mixing wine; the *lebes, chytra, thermanter*, for warming liquids; the *chous, oinochoe, prochous, epickysis*, for pouring out wine; the *arytaina, aryballos, cotyle*, and *cyathos*, for drawing; the *louterion, asaminthos, pyelos, scaphe, lecane, podanipter, holkaion, perirrhanterion, ardanion*, for washing; the *depas, aleison, kissybion, kypellon, cymbion, scyphos, cantharus, carchesion, cylix, therikleios, phiale, acatos, keras*, for drinking; and the *canoun, discos, pinax, paropsis, tryblion, oxybaphon*, and *oxis*, for holding food. A few ancient vases have been identified with their names, but many still remain obscure. The names of the Roman vases, with some exceptions, are equally difficult to determine. The dishes for the table were the *patina* and *patella*, the *catellum* and the *lanx;* pots for cooking, the *olla* and *cacabus;* and drinking vessels, the *calix, patera, ciborium, scutella*, and *concha;* the oil jugs, the *ampulla, guttus, guttulus, gutturinum*, and *concha;* while for mixing and pouring out wine, the *amphora, lagena, cadus;* and for keeping it in the cellars, the huge *dolia* or vats were in constant use. The *capis, capedo, simpulum*, and *simpuvium* were sacred vessels, and often of earthenware. The Roman poets indeed often use the Greek names of vases, but these were apparently borrowed from the poets of Greece, whose effusions they imitated. The Roman vases are of metals and earthenware [POTTERY], lead, pewter, and box-wood.

Amongst oriental nations the vases of China are most remarkable for their antiquity, size, and beauty; the principal shapes of the metallic vases are wine-jugs, *tsun;* cups, *e;* pails, *yew;* teapots, *hoo;* incense vases, *tung;* and tripods, *ting*. Some of the metallic vases are of great antiquity, as old as the Emperor Chingtang, of the Shang dynasty, B.C. 1743, and engraved with characters of a hieroglyphic nature. Some were given as honorary rewards, those offered to the emperor being made of gold, while the nobility received vessels of fine copper, and the literati iron. Others were used for ancestral worship, or for holding sticks of incense in the Buddhist and other temples. At an early period honorary vases were buried with the dead, but about B.C. 200, Che-hwang-te, of the Tsin dynasty, exhumed the graves of ancient sages, and many ancient vases were discovered. The vases with three feet are supposed to allude to the stars presiding over the prince, mandarin, and people. Those with four, to those stars presiding over the four civil officers. The device of the eyes of a tiger is supposed to warn against drunkenness or gluttony; the mæander, or 'thunder pattern,' to agriculture; the characters cow, *new;* sheep, *yang;* hog, *she;* to agricultural merit. The inscriptions, generally in ancient seal characters, are the names of the person, the vessel, the date, the object for which it was given, and other details. Many of the Chinese vases of later periods are beautifully enamelled in various colours, and of great value: others are elegantly damascened with gold and silver patterns. The vases dated in the years of Seuentih, A.D. 1426–36, are said to be made of a mixed metal of gold, silver, and brass, accidentally produced at the burning of the palace. Those of porcelain have been already described. [POTTERY.] Other vases are made of jade, soapstone, and the horn of the rhinoceros, which was supposed to be an antidote against poison.

In Europe, during the middle ages, vases of rock crystal continued to be made till the capture of Constantinople by the Turks in the 15th century, when the art was transferred to Western Europe; and rock crystal, heliotrope, and jasper were used by Italian artists for this purpose till the 17th century, when the art was abandoned, although subsequently revived in the 18th century. The goldsmiths indeed, from the 12th century, had introduced vases ornamented with damascene and niello work, and many elegant examples were made in Italy, especially by Cellini. As early as the 12th century glass vases of filagree work, made by a peculiar process, were produced at Venice, and the manufacture was only abandoned in the 18th. Many of these were of fantastic shapes. German vases, of cylindrical shape, with enamelled paintings of armorial bearings and other devices, were invented at a later period.

The Arabian vases of the middle ages are chiefly of metallic or glazed ware. [POTTERY.] The first kind consists chiefly of ewers and basins for washing the hands, and are generally of latten, a mixture of copper and tin, chased or stamped, and embellished with knobs, arabesques, mosaic and damask work slightly tooled out, *champlevé*, or chased out, the ground lowered and pricked or pounced, and the silver pressed upon it. Many were made at Mossoul, in Mesopotamia, as early as the 12th century.

In modern arts vases still continue to play a part, although not so important as those of the ancient world. Russia is probably the country where the largest and costliest specimens are produced, in jasper, malachite, quartz, and other hard rocks, chiefly from stones found at Orsk, in Orenburg, in Siberia, the sites of the manufactures being placed at Perm and Tomsk. The island of Malta also produces small vases in hard stone, carved in the style of the renaissance; and Tuscany is remarkable for its vases of the pure white alabaster of Volterra, very elaborately and tastefully carved, for the purposes of decoration. England, France, and Austria also produce elegant vases of cut and coloured glass, the successors of the old filagree glass vases of the Venetians; and the European nations fabricate ornamental vases in all metals for prizes, presents, or decorations, each in their peculiar style of art and taste. The invention of electrotyping and the increase of luxury have given a new stimulus to this branch of the fine arts.

(Birch, *History of Ancient Pottery*, 8vo, Lond. 1858; Thoms, *Dissertation on Ancient Chinese Vases*, 8vo, Lond. 1851; Labarte, *Illustrated Handbook of the Arts of the Middle Ages*, 8vo, Lond. 1858; Kramer, *Ueber den Herkunft Griech. bemahlt. Vas.*, 8vo, Breslau, 1846; Krause, *Angeiologie*, Halle, 1854.)

VASSAL. [FEUDAL SYSTEM.]

VAUDEVILLE. *Aval*, or *à-vau*, is a phrase among navigators, implying the reverse of *amont*. *Avau de l'eau* is used adverbially to express drifting down a stream:—"Personne ne ramoit, nous nous laissions aller à-vau de l'eau." Vaudeville appears originally to have been applied to designate any song or ballad borne along on the current of town gossip or popularity—*à-vau de ville*. It has been customary among etymologists to maintain that the word was originally *vau-de-vire*, from the valley of Vire in Normandy, "where gay and malicious songs were composed centuries ago, which had great currency." No evidence has ever been adduced in support of this legend, and the kind of rhymes originally designated by the word vaudeville are quite as likely to have originated in populous towns and their gossiping crowds, as in a Norman valley. "Vaudeville," we read in the 'Dictionnaire de l'Académie,' "signifies a popular song, the air of which is easily sung, and the words composed upon some story of the day." From songs the term was extended to pamphlets and theatrical pieces founded on ephemeral gossip. At present the theatrical application of the name has superseded the others. Theatrically speaking, a vaudeville is a short drama, the dialogues of which are interspersed with short songs set to popular airs. The principal charm of the vaudeville consists in its covert allusions, its delicate raillery on the leading characters and events of the time. The plot ought to be simple—rather sketched or indicated, than developed—and the characters presented in the same slight manner. The interest ought never to be sufficiently serious to divert attention from the interchange of playful sarcasm and simple melodies which all can appreciate. The vaudeville charms by its brilliant and easy dialogue, its snatches of apparently impromptu music and song, and its least possible spice of malice: any attempt to give a show of reality to the story and persons of the drama would render the elegant trifle ponderous and stupid. Hitherto French authors alone (with perhaps the exception of Göthe) have succeeded in composing, and French actors in representing, these charming nothings: the graceful levity of the vaudeville can scarcely ever bear translation into the more sinewy languages of Europe. Among all French authors of vaudeville, the palm is undoubtedly due to the late M. Scribe of the thousand dramas.

VAUDOIS (Waldenses, or Valdenses; in Latin *Vallesi; Valdési* in Italian; *Vaudés* in their own dialect), a remarkable people, who form a communion separate from the Church of Rome, and who live in three high valleys of Piedmont, on the eastern or Italian side of the Cottian Alps, between Mount Viso and the Col de Sestrieres, in the province of Pignerol. The valleys are—1, that of Lucerna, through which flows the Pelice, an alpine torrent which rises in the Col de la Croix, near Mount Viso, and flowing eastward, falls into the river Clusone; 2, Valley of Perosa, through which passes the Clusone, which rises in the Col de Sestrieres, flows in a south-east direction by Fenestrelle, Perosa, and near Pignerol, and, after receiving the Pelice, joins the Po a few miles further down; 3, Valley of San Martino, which branches out of the valley of the Clusone, along the course of a torrent called Germanasca, which rises in the Col d'Aliries. The Vaudois are distributed in thirteen parishes, each having its pastor, called *barbe* in their dialect. One of the pastors bears the title of moderator, being superior in authority to the rest. In former times, when the Vaudois communion was much more extended than it is now, they had bishops, who are mentioned in several old documents. In every parish there is a Vaudois church and a school, besides a church for the Roman Catholic population. The Vaudois clergy are allowed to marry. They take no fees for burials, baptisms, or marriages. The Liturgy now in use is that of Geneva, in the French language: formerly they made use of a Liturgy in Italian. The spoken dialect of the people resembles the other dialects of Piedmont. The origin of the name Valdenses, or Valdesi, is found in the word *vallis*, and means inhabitants of the valleys. Its derivation from Peter Waldo, or Valdo, of Lyon, a merchant of the 12th century, who was a religious reformer, caused portions of the Bible to be translated into French, and was the founder of the sect called the Poor Men of Lyon, is now abandoned. Waldo, being condemned by the archbishop of that city, A.D. 1172, and afterwards by Pope Alexander III., emigrated to Germany, and is said to have died in Bohemia. The Vaudois of Piedmont however existed as a religious community long before Waldo, whom Beza even suspects of having derived his tenets, if not his name, from them. From him, however, the separatists from Rome in the south of France have been called Waldenses, and this has caused them to be confounded with the Vaudois, or Vaudés, of the Alps, although the doctrines and discipline of some of the former were not always in accordance with those of the Vaudois. The real Vaudois remained in the valleys east and west of the Cottian Alps. The Albigenses properly so called were quite distinct from the Vaudois. [ALBIGENSES.]

This little community is remarkable for having kept itself from time immemorial separate from the Church of Rome, in ages when that church is generally considered as having been the only existing church in the West, and for being the only Italian church which continues to this day separate from Rome. We have memorials of the doctrines of the Vaudois written in the early part of the 12th century: their tenets were then such as they are now. The 'Nobla Leyçon' is a sort of abridgment of the history and doctrine of the Old and New Testaments. It speaks of the mission of the Apostles and of the primitive church, and of certain practices that were introduced afterwards in its bosom: of simony, the institution of masses and prayers for the dead, of absolution, and other tenets of the Church of Rome, which it rejects. It is a poem in the Vaudés dialect, nearly the same as that which is spoken at the present time, and records in the text its having been composed in the early part of the 12th century.

There is also a confession of faith of the Valdenses, bearing date A.D. 1120, acknowledging the Apostles' Creed and the canonical books of the Old and New Testaments, recognising no other mediator and advocate with God the Father but Jesus Christ, denying purgatory, admitting only two sacraments—Baptism and the Lord's Supper—as signs or visible forms of the invisible grace, discarding the feasts and vigils of saints, the abstinence from flesh on certain days, the mass, &c. And another manuscript dated 1100, speaks of the Valdenses as having maintained the same doctrines from time immemorial in continued descent from father to son, even from the times of the Apostles. Besides these, there are two controversial treatises, one entitled 'Of Antichrist,' and the other upon 'The Invocation of Saints,' which seem to bear this internal evidence of their antiquity, that in enumerating the various tenets and practices of the Roman Church which the Valdeuses reject, they speak of the doctrine of the real presence, and of the adoration of the Virgin Mary and the Saints, but in so doing they do not use the words transubstantiation and canonisation. Now the term transubstantiation was first introduced under Pope Innocent III., and confirmed in the council of Lateran, A.D. 1215, and the first papal bull in which the word canonisation occurs is dated 1165. Nor do these treatises speak of the devotional exercise of the Rosary introduced by St. Dominic, nor of the Inquisition, which began in the 13th century. Had those institutions existed when the treatises were written, they could hardly have escaped the notice of the writer. Manuscript copies of these and other ancient documents relative to the Vaudois, amounting to twenty-one volumes, were brought to England by Sir Samuel Morland, who was sent by the Protector Cromwell as envoy to the Duke of Savoy in 1655, and were by him presented, in 1658, to the library of the University of Cambridge. Morland wrote a 'History of the Evangelical Churches of the Valleys of Piedmont,' London, 1658, giving a transcript and English translation of the 'Nobla Leyçon.' P. Allix, D.D., who published 'Remarks upon the Ecclesiastical History of the Antient Churches of Piedmont,' in 1690, notices the manuscripts brought by Morland. But now only fourteen out of the twenty-one volumes are existing in the University Library, and nobody can tell what is become of the rest. The 'Nobla Leyçon' is one of those which are missing. In 1669, Jean Leger, a pastor of the Valdenses, published at Leyden, 'Histoire Générale des Eglises Evangéliques des Vallées du Piémont,' in two books, the first of which treats of the early date and continuity of their doctrine, and he gives transcripts of several of the manuscripts brought to England by Morland.

The question about the early date of the 'Nobla Leyçon,' the Vaudois confession, and the other manuscripts above mentioned, is of considerable importance in an historical as well as a religious point of view. There is however further evidence brought forth for the antiquity of the Vaudois doctrines. The name of Valdenses does not appear in historical records till the end of the 12th or early part of the 13th century, but we find allusions as early as the 9th century to the existence of non-conformist churches on the borders of Italy. Jonas, bishop of Orleans, in his work 'De Cultu Imaginum,' addressed to Charles the Bald, A.D. 840, speaks of Italian churches which he accuses of heterodoxy because they refused to worship images, and he charges Claudius, bishop of Turin, with encouraging the people of his diocese in their separation from the Catholic unity.

The fragments existing of the works of Claudius show his opinions concerning faith and merits, prayers after death, the worship of images, the invocation of saints, tradition, and church authority, to have been the same as are expressed in both the old and modern Vaudois catechisms, as well as in the catechisms of the modern reformed churches. And it is worthy of remark, that Claudius in his epistle, 'Ad Theodemirum,' says, in reply to the charge of promulgating novelty in religion, "I teach no new sect, but keep myself to the pure truth, and I will persist in opposing to the uttermost all superstitions and schisms." Claudius died about A.D. 840, and contemporary with him Agobardus, bishop of Lyon, as appears by his 'Treatise against Pictures,' edited by S. Baluze, was also preaching against the worship of images. The valleys of the Cottian Alps must have been under one or the other of these bishops. In the synod held at Arras, A.D. 1025, it was represented to the president, Bishop Gerard, that certain persons had come from the borders of Italy and had introduced heretical dogmas about the nature of justification, the real presence, and against images, relics, altars, &c. About 1140, Bernard of Clairvaux, in his sixty-sixth sermon upon the Canticles, speaking of heretics who then were disturbing the church, mentions, among others, "a sect which calls itself after no man's name, which affects to be in the direct line of apostolical succession, and rustic and unlearned though it is, yet it contends that we are wrong and that it only is right. It must derive its origin from the devil, since there is no other extraction which we can assign to it." The Valdenses have always rejected any distinctive sectarian appellation, and have boasted of adhering from age to age to the primitive faith. In the bull of Pope Lucius, A.D. 1183, four years after the Lateran council, in which the Albigenses were anathematised, several sorts of heretics are mentioned, Cathari, Paterini, the Poor Men of Lyon, and the Passagini, or men of the passes, as lying under a perpetual anathema. And in 1194, Alfonso, king of Aragon and marquis of Provence, issued an edict, "commanding the Valdenses, the Insabbatati, who otherwise are called the Poor Men of Lyon, and all other heretics, to depart out of his dominions." About 1230, Reinerus, a Dominican, who states that he had been himself a heretic, wrote a treatise against heretics, 'Opusculum de Hæreticis,' in which he speaks, among others, of the Leonists, or Poor Men of Lyon ("Secta Pauperum de Lugduno qui etiam Leonistæ dicuntur"), and describes their tenets, which are exactly the same as those contained in the old records of the Valdenses as well as in their modern catechism. The Valdenses and the Poor Men of Lyon (Valdenses sive Lugdunenses) are confounded together in the chronicles of that age; and in the Chronicon of Abbas Ursbergensis (A.D. 1212) the Pauperes de Lugduno are represented as an ancient order which arose in Italy long ago. Reinerus begins by saying, that these Leonists or Pauperes were the most pernicious of all the sects, for three reasons: 1, because they are the most ancient—more ancient than the Manichæans or Arians, dating their origin, according to some, from the time of Pope Sylvester I., and according to others from the time of the Apostles; 2, because they are more universally spread; 3, because they have the character of being pious and virtuous, as they believe in the Apostles' Creed, and are guilty of no other crime than that of blasphemy against the Roman Church and clergy. This book of Reinerus is very important, but we must refer those who wish for further information to the Rev. W. S. Gilly's 'Second Visit to the Vaudois of Piedmont,' section iii., where the author has placed in parallel columns passages from Reiner's text, the corresponding opinions of Italian writers previous to the 12th century, and those of the ancient and modern Valdenses concerning the same topics.

When Marcus Aurelius Rorenco, grand-prior of St. Roch, was sent by Duke Charles Emmanuel, about the middle of the 17th century, to make inquiries concerning the Vaudois, he reported that "these Apostolicals, as they call themselves, were of an origin of which nothing certain could be said, furthermore than that Bishop Claudius might have detached them from the church in the 8th century, and that they were not a new sect in the 9th and 10th centuries." And the monk Belvidere, who went to the valleys of the Cottian Alps on a similar inquiry, reported "that heretics have been found in the valley of Angrogna in all periods of history." Claude Seissel, archbishop of Turin, A.D. 1500, spoke of them as "the Vaudois sect, which originated with one Leon, a devout man, in the time of Constantine the Great." From all the above testimonies it is contended, with considerable show of argument, by the Vaudois, that they are not a sect that sprung up in the 12th century, or was introduced by emigrants from abroad, but that they are an aboriginal Alpine community, the offspring of early Christianity implanted in these remote districts. The earlier edicts of the dukes of Savoy speak of the "men of the valleys" and their "ancient faith," which "it had been found impossible to eradicate from thence, and which the dukes had been constrained to tolerate." An edict of 1584 speaks of privileges granted by former dukes, and cites edicts of 1448 and 1452. In the 'Theatrum Statuum R. C. Sabaudiæ Ducis,' published in 1682, it is stated that treaties four hundred years old secured personal and religious freedom to the Vaudois.

It is an historical fact that, some time in the 14th century, a colony of emigrants from North Italy, professing the tenets of the Vaudois, settled in Calabria, where they cleared the ground of whole districts, and became thriving tenants of the great landlords. They built the towns of La Guardia (which is still called Guardia Lombarda), San Sisto, La Rocco, and others, not far from Cosenza, where they lived in peace and unnoticed for about three centuries. But after the spreading of the Reformation in the 16th century they began to correspond with Geneva and other places, and invited some Protestant divines to come among them. This excited the attention of the local authorities; and the Duke of Alcalá, viceroy of Naples, sent commissioners and monks with troops to convert or destroy them. They resisted, and were destroyed with circumstances of great barbarity, in 1561. (Botta, 'Storia d'Italia,' book x.)

At one time the valleys of the Vaudois were subject to the marquises of Saluzzo; and the Vaudois have repeatedly asserted, without being contradicted, that "their ancestors professed their ancient faith long before the dynasty of Savoy was established in Piedmont." Their religious community extended then over many other valleys on both sides of the Alps; to the southward beyond the Po over part of the marquisate of Saluzzo, westwards in the valley of the Durance as far as Embrun and Briançon, and northwards to the banks of the Dora. The valleys of Queiras and Frassinière in France, and that of Pragelà in the province of Susa, at the foot of Mount Genèvre, professed their communion till within comparatively recent times. In the two former valleys there are still scattered evangelical congregations, in the villages of Dormilleuse, Frassinière, and Violin.

Concerning the persecutions which the Vaudois have sustained, and which fill up a large portion of their history, we must not trust implicitly either to Leger and the other Vaudois writers, who were themselves actors or sufferers in these occurrences, nor to the accounts of their persecutors. We prefer following a modern historian, Botta, a Piedmontese and a Roman Catholic, but a temperate, discriminating writer, far removed from those scenes of strife, and from the passions which excited them or were the consequence of them. The earlier persecutions of the Vaudois were the work of the inquisitors sent by Rome. Pope John XXII. issued a bull against them in 1332. Walter Lollard, who was burnt at Cologne in 1350, was a Vaudois clergyman. About the year 1400 a persecution is recorded against the inhabitants of Pragelà and the valley of Perosa, in which many perished. In 1487 Innocent VIII. issued a bull to Alberto de Capitaneis, papal nuncio and commissioner for the dominions of the Duke of Savoy on both sides of the mountains, enjoining "him to extirpate the pernicious sect of malignant men called the 'poor people of Lyon,' or the Waldenses, who have long endeavoured in Piedmont and other neighbouring parts to ensnare the sheep belonging unto God, under a feigned pretence of holiness," &c., and if expedient "to preach the crusade against them." But it was not until the following century that a general proscription took place. When Luther, Zwingli, and Calvin began preaching their reformed doctrines, the Valdenses acknowledged them to be similar to their own. Francis I. of France, who was also possessed of Piedmont, persecuted all heretics indiscriminately, whether of the new Reformed faith, or of the old Waldenais or Vaudois communion, and determined on extirpating them. The massacres of Dauphiné and Provence, especially at Merindol and Cabriere, are recorded in history. He at the same time wrote to the parliament of Turin, enjoining it to enforce religious conformity within its jurisdiction. The Vaudois of Piedmont then drew up a list of their articles of faith and laid it before King Francis, begging to be allowed to retain their ancient form of worship; to which Francis replied, that as he was putting to death the heretics in France, he could not tolerate them on the other side of the Alps. The parliament of Turin commanded the Vaudois to drive away their barbes, or pastors, and to receive Roman Catholic priests, who would be sent to instruct them. The Vaudois refused, and persecution followed. Several Vaudois who refused to renounce their faith were burned alive. (Botta, b. iv.: A.D. 1541-4.) Still their communion was not extirpated; and years after, Piedmont having been restored to the house of Savoy, Duke Emmanuel Philibert, after being repeatedly urged by the inquisitor Giacomello, sent by Pope Paul IV., ordered, in 1560, the Vaudois to attend the Roman Catholic service, and forbade them the exercise of their own form of worship under penalty of 100 golden "scudi" for the first transgression, and of the perpetual galleys in case of relapse. The Vaudois wrote an humble supplication with an apology for their faith to the duke, who, being little conversant with theological controversy, proposed a conference between the Vaudois and Roman Catholic divines. But Pope Paul IV. disapproved of this; and at last, being importuned by the inquisitor and the nuncio, and the court of Spain, the duke resorted to arms to enforce obedience. He sent into the valleys 7000 men under the Count of La Trinità, to whom the French king joined two regiments on the side of France. The French court at that time was persecuting the Huguenots, who were numerous in Dauphiné, and who were disposed to make common cause with the Vaudois. The Vaudois defended themselves bravely, and in one instance defeated the ducal troops at Pra di Torre. Many atrocities were committed in this desultory warfare, and women and children were not spared. Some of the prisoners were burnt alive at Carignano, Susa, and Piñerola. At last Duke Emmanuel Philibert, disgusted with this war, into which he had been pressed against his wish, and urged by the intercession of his wife, Margaret of France, who pitied the Vaudois, granted them, in June, 1561, peace and an amnesty, with the exercise of their religion, within certain stated limits, in the valleys of Lucerna and San Martino, on condition that the Roman Catholic service should also be performed simultaneously, in churches appropriated to the purpose in the various villages. This edict was signed by Philip of Savoy, lord of Racconigi on one part, and by two of the principal pastors of the Vaudois on the other. The court of Rome and the monks in Piedmont declaimed loudly against these concessions of Duke Emmanuel Philibert, and almost called him a heretic. (Botta, b. x.)

In 1601 and 1602 Charles Emmanuel I. confirmed to the Vaudois their religious immunities, but the Inquisition was molesting them at the same time, and even imprisoned some individuals, and when remonstrances were made to the ducal ministers, they replied, "These matters do not concern his highness." (Botta, b. xv.) The duke however issued two rescripts, dated 1603 and 1620, guaranteeing to the Vaudois the exercise of their religion within the limits prescribed in the three valleys of Lucerna, Perosa, and S. Martino. The Vaudois had asked the same favour for their co-religionists in the Marquisate of Saluzzo, but this was refused. Charles I. of England sent twice an embassy to the duke to intercede for the Vaudois, in 1627 and 1629. (Appendix to Gilly's 'First Excursion to the Mountains of Piedmont in 1823.')

Victor Amadeus I., who succeeded Charles Emmanuel, published an edict enjoining the non-conformists of the Marquisate of Saluzzo, who were chiefly in the communes of Pæsana, Praviglielmo, Bioleto, Bretonni, and Croesso, to embrace the Roman Catholic religion, under penalty of death and confiscation of property; and this edict was so strictly enforced, that not one non-conformist remained in those parts. But at the same time the duke issued an edict to protect the Vaudois of the valleys of Piñerola, who have always been held distinct from the others, and to check the prevailing practice among the Roman Catholic priests and laity of kidnapping the children of the Vaudois in order to bring them up in the Roman faith. (Botta, b. xxi.) After the death of Victor Amadeus, and during the civil war which raged in Piedmont, the Vaudois remained faithful to their lawful duke, and opposed by arms the factious marquises of Lucerna and Angrogna, who sided with Prince Thomas and the other pretenders to the Regency, and they were accordingly confirmed in their privileges by the Duchess Regent, and by the young Duke Charles Emmanuel II. But the same Charles Emmanuel afterwards directed a most fierce persecution against the Vaudois. Botta attributes the origin of this fresh storm to the turbulent disposition of Jean Leger, a pastor of some name among the Valdenses, who had more zeal than prudence. In March, 1653, the inhabitants of Villaro, in the valley of Lucerna, rose in a tumult, and drove away the Capuchins from their convent, to which they set fire. The ducal troops repaired to the spot, and, after some bloodshed, peace was re-established. But this affair led to further investigations, when the ducal government found out that the Vaudois had transgressed against their engagements by purchasing property and establishing schools and places of worship beyond the limits fixed by former edicts. In January, 1655, the duke caused his auditor Andrea Gastaldo to proceed to Lucerna, when he issued a manifesto ordering all Vaudois families to evacuate within three days the communes of Lucerna, San Giovanni, La Torre, Bibbiana, Fenile, Campiglione, Bricherasco, and San Secondo in the lower part of the valley of the Pelice, and retire to the higher part of the valley, to the communes of Villaro, Bobbio, Rorà, Angrogna, and Boneti. Within twenty days they were either to sell their property situated in the former districts or to embrace the Roman Catholic faith. The Vaudois resisted this command, and the duke sent the marquis of Pianezza with a body of regulars and some militia in the following April. The Vaudois deserted their villages, carrying their provisions to the mountains. The marquis followed them there, but he could not subdue them; and his soldiers, finding nothing to eat, withdrew. The Vaudois then issuing from their recesses, under two determined leaders, Jayer and Janavel, fell upon several Roman Catholic villages, and plundered and burnt them. They then entered La Torre, but being surprised by Pianezza, they fought desperately and most of them fell, but not without killing numbers of the ducal troops. In this warfare cruelties were committed by both parties, but the Vaudois, being the losing party, were, with their families, the greatest sufferers. Many atrocities were committed against the women and children by the Piedmontese soldiers, but still more by the mercenary French and Irish soldiers in the service of the duke, which horrors Jean Leger, who was an actor in the struggle, has detailed at length, and, Botta thinks, has exaggerated in his 'Narrative.' But there is a document in the University Library at Cambridge which tells strongly against the marquis of Pianezza himself. It is a declaration by Captain Du Petit Bourg, who was serving in a French corps under Pianezza, protesting against the cruelties which he saw committed, and for which he retired and quitted his corps. He says that the marquis ordered to give no quarter, saying that his highness was determined to have none of their religion in his dominions. This protest, a copy of which is given by Gilly in his first work, is dated Piñerola, 25th November, 1655, and is attested by other officers. It appears, however, that Pianezza ordered the women and children to be spared, and he rescued many from the hands of the brutal soldiers, and distributed them in the neighbouring districts of Piedmont. A number of Vaudois took refuge across the mountains in the French valley of Queiras, and returned after the fury of the massacre had abated. Others perished in the snow, and others lurked for a time in the recesses of the mountains, under their chief Janavel, who carried on a partisan warfare until he was killed some years after.

The news of the massacre of the Vaudois spread far and wide throughout Europe. The Protestant cantons of Switzerland, the Protector Cromwell, and the States of Holland, sent envoys to the duke of Savoy, to remonstrate in favour of the Vaudois. Cromwell sent Sir Samuel Morland, who collected numerous documents, and published them in his 'History of the Evangelical Churches,' fol., 1658. Cromwell's Latin letters to the duke and other princes on the subject were written by Milton, who in one of his sonnets has feelingly lamented the cruelties committed against the Vaudois. Subscriptions were made in England and other countries for the survivors. At last, at Cromwell's request, Louis XIV. offered his mediation, which the duke accepted, and a convention was concluded in August of the same year, 1656, at Piñerola, which then belonged to France, by which a general amnesty was granted, and the Vaudois were allowed to remain on the left bank of the Pelice within certain fixed boundaries, and to have the exercise of their religion, but at the same time it was agreed that the Roman Catholic worship should be performed in the same villages, and Catholic missionaries be sent to preach there, but no Vaudois should be constrained to become a Roman Catholic, and no girl under ten, and no boy under twelve years of age, should be taken from their parents. This convention was signed by Jean Leger and other Vaudois pastors. But after some years new complaints and disputes broke out, which Count Bagnolo, the governor of the province, wanted to settle in an arbitrary manner. Fresh resistance and a new persecution took place in 1663 and 1664, followed by a new edict of the duke, by which the Vaudois were forbidden to perform their worship in the village of S. Giovanni. Jean Leger emigrated, and visited various countries, urging the claims of the Vaudois and collecting subscriptions for them. He was at last appointed minister of the Walloon Church at Leyden, where he died. (Botta, b. xxv.)

Victor Amadeus II. succeeded Charles Emmanuel, and took the reins of goverment at the end of 1684, being then eighteen years of age. Piedmont was then the humble ally of the imperious Louis XIV., who about this time resolved to abolish Protestantism in France by the revocation of the Edit de Nantes, and he ordered Victor Amadeus to do the same with regard to the Vaudois. After some demur the duke was induced to submit, and in January, 1686, he issued an edict ordering the Vaudois either to abjure their tenets within fifteen days, or leave their country. Driven to despair, the Vaudois determined to resist. They were attacked on one side by the ducal troops, and on the other by those of Louis XIV., commanded by Catinat. After a gallant struggle the Vaudois were overpowered, and the survivors were obliged to submit unconditionally. Their whole property was confiscated, and given to Roman Catholic colonists, the old inhabitants with their families taking their departure for Switzerland. Those who had been taken prisoners were distributed in various prisons, in which a number of them died. At the expiration of three years, a band of 800 of these emigrants, under the command of one of their pastors, Henry Arnaud, undertook one of the most daring and romantic expeditions ever attempted by men. [Arnaud, Henri, in Biog. Div.]

This was the last persecution against the Vaudois; who however remained subject to various disabilities and exposed to several vexations, which are detailed by Gilly in his first excursion, p. 116; and in the second, p. 546, and fol.

In the wars of the French revolution the Vaudois remained loyal to their sovereign, and bravely defended for years the mountain-passes through which the French threatened to invade the valley of the Po, which ultimately they reached, but not on this side. In June, 1794, King Victor Amadeus III. published an ordinance, in which, after acknowledging the constant and distinguished proofs of their attachment and fidelity, he promised to redress several grievances, among others, that of taking away of children of the Vaudois, with the view of obliging them to embrace the Roman Catholic religion. He forbade the practice, and ordered those who had been so taken away to be restored. "Those who at the prescribed age, girls at ten and boys at twelve, voluntarily enter the hospital of Piñerola, must be under the direction of ecclesiastical judges; but no difficulty will be made in permitting the parents to see their children under proper precautions."

When Bonaparte annexed Piedmont to France, he placed the Vaudois on a footing of equality with their Roman Catholic countrymen, and assigned funds for the support of their clergy. At the restoration in 1814 the Vaudois were again placed under their former disabilities, and those who had purchased land beyond the limits of their valleys were obliged to sell it to Roman Catholics. King Charles Felix, who succeeded to the throne in 1821, showed some more indulgence towards the Vaudois. Under the present king of Italy, Victor Emmanuel, they have been admitted to an equality of rights with their fellow subjects.

VAULT, VAULTING. The continuation of an arched covering over a considerable surface is commonly spoken of in the Arts under the name of *vaulting;* and occasionally the word *vault* is applied to the actual assemblage of the voussoirs of an arch, in contradistinction to the haunches, spandrils, or other supplementary parts. Both of these significations may be retained without inconvenience, because they express conditions it may often be necessary to refer to in practice, and for which it is desirable to possess names.

There is little to be added to what has been already said under Arch and Bridge, with respect to the mechanical principles of vaulting, excepting that in the case of intersecting arches it may be desirable occasionally to form the lines of intersection by arched ribs, springing from the respective abutments, but even in this case the resolution of the thrust must ultimately be the same, in principle, as in any ordinary arch. It is customary in practical works on architecture and engineering, to class the various descriptions of vaults as follows:—1, Waggon-headed and semicircular vaults; 2, Domical vaults; 3, Pointed arched vaults; 4, Groined arches, which in their turn may be made to pass through numberless modifications, according to the positions assigned to the various ribs, pillars, or points of support. It is in the latter form of vaulting that the fan tracery so much admired in Gothic architecture occurs; and the skill with which the mediæval architects concentrated the strength of the vaulting in the ribs, whilst they reduced the thickness of the spandril filling, enabled them to secure effects of the most elaborate and pictorial character. In the simple square groin the ribs near the wall, and those at the intersection of the arches, perform the office of supporting the vaulting; in the more ornate fan tracery, other ribs are introduced, so as to form, on plan, a star of four points, or the primitive arches may rise to different heights, either ultimately meeting by intersection, or truncated in the middle of the space. Polygonal spaces were covered in the mediæval period either by means of a series of fan-shaped ribs, starting from arches applied against the external wall, and from a central column, as in the cases of many of our chapter-houses, or by groined arches spanning the whole space between the walls; or by pendentive roofs, when the internal dimensions are not very great. Excellent examples of the first of these systems of vaulting over polygonal buildings are to be found at Winchester, Salisbury, Wells, Lincoln, &c.; of the second, at Durham, York, &c.; and of the third at Caudebec. In many of Sir C. Wren's churches, the system of groined vaulting has been applied with as much boldness and artistic success as in the buildings of the mediæval architects; but the compulsory use of the semicircular arch in the Italian architecture, rendered the intersections of the side vaults with the principal ones less susceptible of ornamental decoration than is the case with the diagonal ribs of the preceding style. The vaulting of St. Paul's, and of St. Peter's at Rome, may be referred to as illustrations of the most effective specimens of this mode of construction as applied to modern cathedrals. It must not be forgotten, however, that the ancient Romans had proved themselves to be perfectly able to overcome all the practical difficulties of vaulting; and the ruins of the palaces of Nero and of Diocletian, the reservoirs of Possilippo and of Constantinople, and the great church of Sta. Sophia may be cited as illustrations of the various solutions they had discovered of the problem of vaulting large areas.

It may be advisable to call attention to the mode of vaulting adopted in some parts of the London Docks, in which the space covered is vaulted by means of groined arches of brickwork, of elliptical form, springing from granite pillars. In cases where the vaults are intended to store combustible goods of great value, there are such manifest advantages in the use of the granite pillars, instead of cast-iron ones, that, writing under the impressions produced by the fearful misfortune of June 22nd, 1861, the author may be pardoned for dwelling on this detail of fire-proof construction.

(Ware, *Tracts on Vaults and Bridges;* Willis, *Architecture of the Middle Ages;* Gwilt's *Encyclopædia of Architecture;* Rondelet, *L'Art de Bâtir,* &c., &c.)

VAVASSOR, VALVASSOR, a term applied in the ancient records of England, Scotland, France, Lombardy, and Aragon, to persons holding fiefs not immediately under the king or other persons possessing jura regalia (as the duke of Normandy, the earl of Chester, or the bishop of Durham), but under some intermediate lord. It appears also, that to constitute a vavassory, it was necessary that the party should have subordinate freeholders, as vassals holding of his vavassory. (Wilkins, 'Leges Angl.', 247; Bracton, 5 b, 6, 93 b; Ducange.) In England vavassories were generally held by knights' service; but in Normandy, besides the franches vavassories or vavassories nobles, there were socage vavassories held by the rent of a rose, a spur, or a glove, and also *vavassories vilaines.* The possessors of these inferior vavassories were sometimes called "valvassins."

Vavassors are twice mentioned in Domesday, pp. 53 and 1469; and in the laws of William the Conqueror, the relief due from a vavassor to his liege lord is described. (Kelham, 40.) A charter of Henry I. directs that pleas of the division of land between the vavassors of two different lords be determined in the county court. In the great Roll of the Pipe of 31 Henry I., mention is made of the vavassors belonging to the barony of the archbishop of York. In the laws of Henry II. the jurisdiction of vavassors is specified. Madox ('Baronia Anglicana,' note, p. 135), sets out a writ in which that prince requires the residence or constant attendance of all barons and vavassors, who owe service of castle-guard at Rockingham castle. Francis de Bohun, in the time of Richard I., was seised of two honours, one that of Bohun in Normandy, which he held of the king, as duke *per baroniam,* the other in England, consisting of the manor of Fordes, &c., in Sussex, which he held *in vavasseriâ.* ('Abbrev. Plac., in Domo Cap. Westm.' 88.) In the next reign Alice Briewiere claimed Plimtree in Devon, and Depeworth in Somerset and Dorset, assigned to her by her late husband Roger de Pole, on the day he set out for Jerusalem, for the full third part of three vavassories, namely, for the vavassories of the earl of Salisbury, the earl of Vernon, and of the vavassory of Earl William de Bohun ('Ib.', 61 b). In the close rolls of 4 H. III. is a writ to the sheriff of Wiltshire, directing him to give seisin to W. Mandevill, R. Maudut, W. Comyn, and W. de Fontibus of three vavassories of the fee of the Earl of Clare, belonging to the barony of Funtell (Fonthill), which barony Andrew Giffard had, with the assent of King John, resigned to those persons as the right heirs (presumptive) of the barony, reserving the vavassories, which vavassories would appear to have been seized into the king's lands upon the death of Giffard under the advice of the crown lawyers, the council of the minor king being afterwards of opinion that such seizure ought not to have been made. Here, vavassories held of the honour of Clare, appear to have become in some way annexed to a barony held of the crown. In the record and process of the renunciation of Richard II., that prince absolves all dukes, marquesses, earls, barons, knights, vassals, and *vavassors*, and other his liege-men, from their oaths of fidelity (3 Rot. Parl., 410); and about the same period Chaucer, after describing his Franklin, says,

> "Was no where swiche a worthy *vavasour*."

From this time we lose sight of the English vavassor. Numerous subseigniories however still exist, the owners of which, though not so designated, are in truth vavassors. From the inalienable quality of the Duchy of Cornwall, many manors in Devonshire and Cornwall are held, though the name is no longer continued, as vavassories of the duchy; of which there are many in the former county, holden of the duchy honour of Bradninch.

The breaking up of the old feudal baronies, and the frequent forfeitures incurred by those who held immediately of the crown, brought the great and many of the lesser vavassors into the position of immediate tenants to the crown. But as the extinction of vavassories was gradual, no new class of crown tenants arose, as was the case in Germany where the disappearance of the dukedoms of Suabia and Franconia (caused by the extinction of the House of Hohenstauffen in the person of Conradin, beheaded upon the failure of his attempt to recover the kingdom of Naples from Charles of Anjou), gave rise to a new order in the state, namely, the *immediate* chivalry (noblesse immédiate) of the empire, the reichsritterschaft, a body *mediatised* by the Congress of Vienna.

When James I., imitating the practice of France, introduced hereditary titles without peerages, a proposal for giving to the new order the designation of vavassors was rejected, and the novel but more appropriate title of BARONET was adopted.

(Terrien, *Cout. de Normandie*; *Testa de Nevill*, 166 a; Selden's *Titles of Honour*, 513, 520; Cragii, *Jus. Feud.*, 100, 141; Manning's *Serviens ad Legem*, 185, 291 a.)

VEADAR. The name of this month is literally "and Adar," meaning "another Adar." It occurs only in intercalary years, immediately after Adar. [ADAR.] This month has twenty-nine days, and the feast of Purim and fast of Esther, usually observed in the month Adar, are transferred to Veadar in the years where this month is inserted. The last time of this insertion was in 1859, when Veadar began on the 7th of March and ended on the 4th of April. The next will be in 1862, when it will extend from the 3rd to the 31st of March.

VEDA. This word (from the Sanskrit radical *vid*, 'to know'—kindred with the Latin *vid-*, Greek ἰδ-, Gothic *vait*) literally means 'knowing,' or 'knowledge;' but is emphatically used as the name of those ancient Sanskrit works which constitute the basis of Brahmanic belief, and are held by the Hindus to have been revealed to them by their deities. These works were originally three, namely, the *R'igveda*, the *Yajurveda*, and the *Sâmaveda*. At a more recent period a fourth Veda was added to them, but it never obtained that degree of sanctity which was allowed to its predecessors; it is not mentioned, for instance, in the ninth verse of the Purusha-sûkta of the R'igveda, which speaks of the R'ig-, Sâma-, and Yajur-veda; nor in the Chhândogya-Upanishad; nor even in the law book of Manu; for though the latter refers on several occasions to the three Vedas, it speaks only once (xl. 33) of "the revelations of the Atharvângirasas," by this expression alluding to, but not naming by name, the Atharvaveda; and even the writers on the Mimânsâ, a doctrine that has for its object to clear up doubtful passages and to reconcile discrepancies of vaidik texts, are merely concerned in those of the three former Vedas, not in those of the Atharvaveda.

Each of these four Vedas consists of two distinct parts: a *Sanhitâ* or collection of *Mantras*, and a portion called *Brâhman'a*.

Mantra (from *man*, 'to think,' literally 'that by which thinking is effected) means a hymn or prayer. According to the definition given by Mâdhava-Sâyan'a, the celebrated commentator of the Vedas,—in his work on the Mîmânsâ, the Jaiminîya-nyâya-mâlâ-vistara, and in his introductions to the *R'igveda* and Aitareya-brâhman'a,—a *Mantra* is sometimes addressed to the divinity with a verb in the first person; sometimes it ends with the verb 'thou art,' or with the word 'thee;' now it mentions the performance of ritual acts, then it contains praises, invocations, injunctions, reflections, complaints, puts questions or returns answers, &c. (Colebrooke, 'Misc. Ess.' i. p. 308; Müller, 'Ancient Sanskrit Literature,' p. 343; Goldstücker, 'Introduction to the Mánava Kalpa Sûtra, or Pân'ini,' p. 69.) The author of a *Mantra*, as we should say—or as the Hindu authorities state, the saint "by whom it was first spoken," the "seer" or "rememberer" of its text—in short the personage to whom the *Mantra* is supposed to have been revealed, is called its *R'ishi*. The deity to whom "the *R'ishi* seeking for the accomplishment of his objects, addresses his praise," is its *Devatâ* (Yâska's 'Nirukta,' vii. 1). But since there are *Mantras* which contain neither petition nor adoration, the subject of such *Mantras* is considered as the deity that is spoken of; for example, the praise of generosity is the *Devatâ* of many entire hymns addressed to princes from whom gifts were received by the authors. (Colebr., 'Misc. Ess.' i. p. 22.)

A *Brâhman'a* (neuter,—not to be confounded with the masculine word, or the name of the sacerdotal caste),—from *brahman*, prayer, is twofold; according to Mâdhava, it contains "either commandments or explanations;" in other words, it gives directions for the performance of sacrificial acts, and explains the origin and object of the rite, by giving citations of hymns, illustrations and legendary narratives, also by speculations of a mystical and philosophical kind. The *Brâhman'a* portion of the Vedas is therefore the foundation of the Vaidik ritual, which became fully developed and systematised in the ritual works called the *Kalpa-Sûtras*; and it is also the source whence sprang those mystical and theosophical writings, the *A'ran'yakas* and *Upanishads*, which at a later period expanded into the orthodox *Vedânta* philosophy, and which are frequently referred to even by the other philosophical schools, though their orthodoxy is extremely doubtful and widely different from that of the Vedânta doctrine.

That there was originally but one text of each of the four Vedas is plausible enough. Tradition records that the son of Parâs'ara R'ishi, Kr'ishn'a Dwaipâyana, surnamed Vyâsa, "having compiled and arranged the scriptures, theogonies and mythological poems, taught the several Vedas to as many disciples, namely, the R'igveda to Paila, the Yajurveda to Vais'ampâyana, the Sâmaveda to Jaimini, and the Atharvaveda to Sumantu." (Colebr., 'Misc. Ess.' i. p. 14.; Wilson, R'igveda, I. p. xx.) But inasmuch as these saints taught the lessons they had learned to their pupils, who in their turn communicated their knowledge to their disciples, and so forth, it is obvious that great variations must have crept into the text; and we know as a fact, that gradually many schools or *Charan'as* arose, each giving preference to its own readings, and, as particularly in the case of the Yajurveda, to its own arrangement and distribution of the sacred text. Hence it came to pass, that each of these Vedas branched off into various *S'âkhâs* (branches), or as we might say, into various editions, which though in the main concurring in their contents, nevertheless contained verbal differences enough to account for the divisions of their respective schools. A work which treats of these schools, the *Charan'avyûha*, enumerates several of them by name, and states that five, sixty-eight, a thousand, and nine were the respective numbers of the Charan'as of the *R'ig-*, *Yajur-*, *Sâma-*, and *Atharva-veda*. Very few only of these editions have come down to us, and the loss of the greatest part of them is the more to be deplored, as they would probably have enabled us to account for some (and important) differences in the verses common to some or all of these Vedas, and perhaps also for superstitions of later times, which are said to be founded on, but are not countenanced by, the text, as we possess it now, of the R'igveda-Sanhitâ.

If in order to gain an insight into the peculiar character of each of these Vedas, we consult the view entertained of it by the native writings, little aid will be afforded us by the mythological narrative of the S'atapatha-brâhman'a (xi. 5, 8, 1), and Manu's 'Law Book,' (i. 23), which tell us, in the same words, that (Brahmâ), "for the due performance of the sacrifice, drew out the threefold eternal Veda, the R'igveda from fire, the Yajurveda from air, and the Sâmaveda from the sun;" nor will our knowledge be more advanced by a passage from the Bhâgavata (iii. 12-37) and the Vishnu-Purân'a, which inform us (i. cap. 5) that "Brahmâ created the R'igveda .... from his eastern mouth, the Yajurveda .... from his southern, the Sâmaveda .... from his western, and the Atharvaveda .... from his northern mouth." But of greater importance is evidently a statement of the Kanshitaki-brâhman'a which, while omitting to mention the Atharvaveda, calls the Yajur- and Sâma-veda "the attendants of the R'igveda" (Müller, 'Anc. Sansk. Lit.', p. 457). The real bearing of the latter words, however, becomes clear from what Sâyan'a says in his introduction to the R'igveda. After having inferred from the ninth verse of the Purusha-sûkta, mentioned before (comp. Muir's 'Original Sanskrit Texts,' i. p. 6), the precedence in rank of the R'igveda before the other Vedas, he continues: "the Taittirîyas, or followers of the Black Yajurveda, record that whatever sacrificial act is performed by means of the Sâma- and Yajur-veda is (comparatively) slender, whatever is done by means of the R'igveda is strong;" and ... "among the hymns found in the Yajurveda there are many R'igveda hymns, which are to be employed by the Adhwaryu priest; all the hymns of the Sâmaveda come from the R'igveda, and even those who make use of the Atharvaveda read in their own Sanhitâ to a considerable extent, the very hymns of the R'igveda" (Sâyan'a, in Müller's ed. of the 'R'igveda,' i. p. 2). It results from this statement, not only that the R'igveda was held to be prior in rank to the other Vedas, but that it was considered to be older than they, and that the hymns of the Sâmaveda were entirely, and those of the two other Vedas to a considerable degree, extracted from the R'igveda-Sanhitâ. And this information of the celebrated commentator is fully borne out by a comparison of the hymns of the four Vedas. For, though Professor Benfey has shown, in his edition of the Sâmaveda (p. xix), that seventy-one verses of the latter are not met with in the present text of the R'igveda, and that many readings of this Veda differ from those of the Sâmaveda, it does not follow "that the recension of the R'igveda-Sanhitâ took place at a later period than that of the Sâmaveda," nor "that the R'igveda verses occurring in the Sâmaveda are older than those of the present R'igveda text" (Professor Weber, in his 'Akademische Vorlesungen,' p. 9. 62); but, as Professor Müller justly observes ('Anc. Sansk. Lit.' p. 475), that this difference "may possibly be accounted for by the fact, that we do not possess all the S'âkhâs of the R'igveda."

The true nature, however, of this relation between the R'igveda and the other Vedas, appears from the purposes which they were made to serve, purposes, which, according to the concurrent statement of all native authors, are of a ritual or sacrificial character.

A vaidik sacrifice is a piece of machinery of a very complicated kind, A knowledge of it is imparted by a class of writings, the Kalpa works, which will be treated of hereafter. Good care was taken by their authors, or the authorities whence their contents are derived, that no man who intended to perform a regular sacrifice (a *yajamâna*), could satisfy his religious want—which was always connected with some worldly desire, such as the birth of a son, increase of cattle, attainment of military renown, conquest, and the like—without the assistance of one or more priests, who as a matter of course always belonged to the Brâhman'a caste. There were sacrifices which lasted one day, others which went on from two to eleven days, others which took up as many as a hundred days. Accordingly, to perform some sacrifices one *R'itwij*, or priest, sufficed; or, to complete others, four, five, or six priests were necessary; their fullest complement, however, is the number of sixteen, for a seventeenth R'itwij—the *Sadasya*, or superintendent—is not admitted by all authorities; and the assistants of the priests—the slayer, the butcher, the ladle-holder, the choristers, &c.—are not counted amongst the R'itwijs or real priests.

This full contingent of priests is enumerated by Âs'walâyana (S'rauta Sûtra, iv. 1) in the following way. First comes the *Hotr'i*, who has under him three men (*purusha*), the Maitrâvarun'a, Achchhâvâka, and Grâvastut; secondly, the *Adhwaryu*, with the Pratiprasthât'ri, Neshtr'i, and Unnetr'i; thirdly, the *Brahman*, with the Brâhman'âchchhansin, Âgnîdhra (or, Agnîdh), and Potr'i; lastly, the *Udgât'ri*, with the Prastotr'i, Pratihart'ri, and Subrahman'ya (comp. Müller, 'Anc. Sansk. Lit.,' pp. 468, 469, where, by a mistake, some of the *purushas* of the *Brahman* and the *Udgâtri* have changed their places). The same class arrangement, though sometimes in a different order, occurs likewise in other authorities (for example, Kâtyâyana S'r. S. vii., 1, 6; Mâdhava Jaimînîyanyây, iii. 7, 17; see also the note to p. 209, in Wilson's second volume of his translation of the R'igveda).

Now, of these R'itwijs, the Kalpa works enjoin that the Adhwaryu has to perform his duties with the Yajurveda, the Udgât'ri with the Sâmaveda, the Hotr'i with the R'igveda, and that the Brahman "has to set right any deficiency that may have occurred in the religious acts of the three former priests; he must, therefore, be acquainted with all the three Vedas—the Rig-, Yajur-, and Sâma-veda" ('Mâdhava Jaimînîyanyây,' iii. 7, 17; vi. 3, 14; Müller, 'Anc. Sansk. Lit.,' p. 469, ff.) It may be added, moreover, that the Adhwaryu had to mutter, inaudibly, the verses of the Yajurveda, that the Udgât'ri had to chant those of the Sâmaveda—probably in the same manner as the Pentateuch is intoned up to this day by the officiating Jews in their synagogues—and that the Hotr'i had to recite in a loud voice the verses of the R'igveda.

It follows, therefore, that each of these Vedas had its distinct ceremonial; but that no ceremonial was assigned to, and that no distinct priest or class of priests had to use, the hymns of the Atharvaveda. "The Atharvaveda," says Madhusûdana, "is not used for the sacrifice; it only teaches how to appease, to bless, to curse, &c." "Its songs," as Professor Müller observes ('Anc. Sansk. Lit.' p. 447), "formed, probably, an additional part of the sacrifice from a very early time. They were chiefly intended to counteract the influence of any untoward event that might happen during the sacrifice. They also contained imprecations and blessings, and various formulas, such as popular superstition would be sure to sanction at all times and in all countries." And the same scholar infers that it was probably part of the office of the Brahman priest, also, to know and to apply these songs, whenever their effect was supposed to be required for remedying any mistake committed by the other three classes of priests. At all events, it is certain that the Atharvaveda is not comprised among the sacrificial Vedas, and that its later date may be safely concluded from its not being mentioned in those works which regulate the ancient rites, even if such posteriority were not recognisable from the language of those of its hymns which do not occur in the other Vedas.

By comparing, however, the contents of the three sacrificial Vedas with the ritual precepts of the Kalpa works, we may ascertain another important fact. All the verses of the Yajurveda and all the verses of the Sâmaveda are used in one sacrificial act or another. Such, however, is not the case with the verses of the R'igveda. Many of the latter, indeed, are likewise indispensable for sacrificial purposes, as we are taught by the ritual books connected with this Veda; yet a good number remain, which stand quite aloof from any ceremony. This class bears purely a poetical or mystical character; and it may be fairly inferred that even the strong tendency of later ages to impress an entirely sacrificial stamp on each of these Vedas, broke down before the natural and poetical power that had evidently called forth these songs, as it could not incorporate them amongst the liturgic hymns. We may quote, for instance, a hymn from the tenth Mandala of the R'igveda (from Colebrooke's 'Misc. Ess.,' i. p. 33), as an illustration of those which belong to the mystical poetry of this Veda. It runs thus "Then there was no entity nor nonentity; no world, nor sky, nor aught above it; nothing anywhere in the happiness of any one, involving or involved; nor water deep and dangerous. Death was not; nor then was immortality; nor distinction of day or night. But THAT breathed without afflation, single with (*Swadhâ*) her who is within him. Other than him, nothing existed (which) since (has been). Darkness there was; (for) this universe was enveloped with darkness, and was undistinguishable (like fluids mixed in) waters; but that mass, which was covered by the husk, was (at length) produced by the power of contemplation. First, desire was formed in his mind, and that became the original productive seed; which the wise, recognising it by the intellect in their hearts, distinguish, in non-entity, as the bond of entity. Did the luminous ray of these (creative acts) expand in the middle? or above? or below? That productive seed at once became providence (or sentient souls) and matter (or the elements): she, who is sustained within himself, was inferior; and he, who heeds, was superior. Who knows exactly, and who shall in this world declare, whence and why this creation took place? The gods are subsequent to the production of this world; then who can know whence it proceeded? or whence this varied world arose? or whether it uphold itself or not? He who in the highest heaven is the ruler of this universe, does indeed know; but not another can possess this knowledge."

An instance of another kind of R'igveda hymns, which cannot have served any sacrificial purpose, is given by Professor Müller in his excellent work on 'Ancient Sanskrit Literature' (p. 495). It bears a satirical character, inasmuch as it ridicules the elaborate ceremonial of the Brahmans, and is rendered by him thus: "After lying prostrate for a year, like Brahmans performing a vow, the frogs have emitted their voice, roused by the showers of heaven. When the heavenly waters fell upon them, as upon a dry fish lying in a pond, the music of the frogs comes together like the lowing of cows with their calves. When at the approach of the rainy season, the rain has wetted them as they were longing and thirsting, one goes to the other while he talks, like a son to his father, saying, 'akkhala!' (*βρεκεκεξ κοάξκοάξ*). One of them embraces the other, when they revel in the shower of water; and the brown frog jumping after he has been ducked, joins his speech with the green one. As one of them repeats the speech of the other, like a pupil and his teacher, every limb of them is, as it were, in growth, when they converse eloquently on the surface of the water. One of them is Cow-noise, the other Goat-noise; one is Brown, the other Green; they are different though they bear the same name, and modulate their voices in many ways as they speak. Like Brahmans at the Soma sacrifice of Atirâtra, sitting round a full pond, and talking, you, O frogs, celebrate this day of the year when the rainy season begins. These Brahmans with their Soma have had their say, performing the annual rite. These Adhwaryus, sweating whilst they carry the hot pots, pop out like hermits. They have always observed the order of the gods as they are to be worshipped in the twelvemonth; these men do not neglect their season; the frogs who had been like hot pots themselves, are now released when the rainy season of the year sets in. Cow-noise gave, Goat-noise gave, the Brown gave, and the Green gave us treasures. The frogs, who give us hundreds of cows, lengthen our life in the rich autumn." In another hymn of the last Mandala a gambler laments over his evil passion, which beguiles him into sin. All these and similar hymns are evidently of quite a different character than those which praise the power of the elementary gods, and could find their place in sacrificial acts.

But there is further evidence to show that the collection of the R'igveda cannot have borne originally a ritual stamp. When songs are intended only for liturgic purposes, they are sure to be arranged in conformity with the ritual acts to which they apply; when, on the contrary, they flow from the poetical or pious longings of the soul, they may, in the course of time, be used at, and adapted for, religious rites, but they will never submit to that systematic arrangement which is inseparable from the class of liturgic songs. Now, such a systematic arrangement characterises the collection of the Yajurveda and Sâmaveda hymns; it is foreign to the R'igveda-Sanhitâ.

With the exception of the last book, which is of a mystical nature, all the other books of the whole Yajurveda contain verses which are classified according to the special sacrifices at the performing of which they were muttered. The Sanhitâ of the Sâmaveda consists of verses which had to be intoned especially at the moon-plant sacrifice. The arrangement of the R'igveda hymns, however, is quite of a different kind. It resisted the order of a finished ceremonial. The R'igveda hymns are not distributed with reference to sacrificial acts; they are partly arranged according to the divinities to whom they are addressed, and partly according to their authors, the R'ishis, who made them known. They must therefore have preceded the completion of that ceremonial, which is the indispensable condition of the Sâmaveda- and Yajurveda-Sanhitâs.

Having established the general character of the four Vedas, we shall now give a brief outline of their special features and of the principal works which owe them their origin.

The Rig-, or the first and principal, Veda, we possess only in the recension of the S'âkhala school. Its Sanhitâ, or collection of hymns, is arranged on two methods. The one has merely regard to the material bulk; the other seems to be based on the authorship of the Mantras. Both, however, run parallel with one another, without differing in the order of the hymns which constitute the Sanhitâ. According to the first method, the Sanhitâ is divided into eight *Asht'akas* or eighths, each of which is again subdivided into *Adhyâyas* or lectures, an Adhyâya consisting of a number of *Vargas* or sections, and a Varga of a number of *R'ich* or verses, usually five. According to the second method, the Sanhitâ is divided into ten *Man'd'alas* or circles, subdivided into eighty-five Annvâkas or lessons, which consist of one thousand and seventeen (or, with eleven additional hymns, of one thousand and twenty-eight) *Sûktas* or hymns, these again containing ten thousand five hundred and eighty and a half *R'ich* or verses. The first eight of these Man'd'alas begin with hymns addressed to *Agni*, which are followed by hymns addressed to *Indra*. After the latter come generally hymns addressed to the *Vis'we Devâs*, or the gods collectively, and then those which are devoted to other divinities. The ninth Man'd'ala is entirely addressed to the Soma-plant, and is especially connected, therefore, with the Sâmaveda-Sanhitâ; while the tenth Man'd'ala has chiefly served for the collection of the Atharvaveda hymns. Again, as regards their author, the second Man'd'ala contains hymns which are attributed to the R'ishi Gr'itsamada; the third is said to belong to Vis'wâmitra, the fourth to Vâmadeva, the fifth to the Atris, the sixth to Bharadwâja, the seventh to Vasisht'ha, the eighth to Kanwa, the ninth to Angiras. The first and the tenth Man'd'ala are ascribed to the authorship of various R'ishis.

"The worship which the Sûktas describe comprehends offering prayer and praise: the former are chiefly oblations and libations,—clarified butter poured on fire; and the expressed and fermented juice of the Soma-plant, presented in ladles to the deities invoked,—in what manner does not exactly appear, although it seems to have been sprinkled, sometimes on the fire, sometimes on the ground, or, rather, on the *Kus'a*, or sacred grass, strewed on the floor, and in all cases the residue was drunk by the assistants. The ceremony takes place in the dwelling of the worshipper, in a chamber appropriated to the purpose, and probably to the maintenance of a perpetual fire, although the frequent allusions to the occasional kindling of the sacred flame are rather at variance with this practice. There is no mention of any temple, nor any reference to a public place of worship, and it is clear that the worship was entirely domestic. . . . . . . That animal victims were offered on particular occasions may be inferred from brief and obscure allusions in the hymns of the first book; and it is inferrible from some passages that human sacrifices were not unknown, although infrequent and sometimes typical: but those are the exceptions, and the habitual offerings may be regarded as consisting of clarified butter and the juice of the Soma-plant.

"The *Sûkta* almost invariably combines the attributes of prayer and praise: the power, the vastness, the generosity, the goodness, and even the personal beauty of the deity addressed are described in highly laudatory strains, and his past bounties or exploits rehearsed and glorified; in requital of which commendations, and of the libations or oblations which he is solicited to accept, and in approval of the rite in his honour, at which his presence is invoked, he is implored to bestow blessings on the person who has instituted the ceremony, and sometimes, but not so commonly, also on the author or reciter of the prayer. The blessings prayed for are, for the most part, of a temporal and personal description,—wealth, food, life, posterity, cattle, cows, and horses; protection against enemies, victory over them, and sometimes their destruction, particularly when they are represented as inimical to the celebration of religious rites, or, in other words, people not professing the same religious faith. There are a few indications of a hope of immortality and of future happiness, but they are neither frequent nor, in general, distinctly announced, although the immortality of the gods is recognised, and the possibility of its attainment by human beings exemplified in the case of the demigods termed R'ibhus, elevated for their piety to the rank of divinities. Protection against evil spirits (*Râkshasas*) is also requested, and in one or two passages *Yama* and his office, as ruler of the dead, are obscurely alluded to. There is little demand for moral benefactions, although in some few instances hatred of untruth and abhorrence of sin are expressed; a hope is uttered that the latter may be repented of or expiated; and the gods are in one hymn solicited to extricate the worshippers from sin of every kind. The main object of the prayers, however, are benefits of a more worldly and physical character: the tone in which these are requested indicates a quiet confidence in their being granted, as a return for the benefits which the gods are supposed to derive from the offerings made to them, in gratifying their bodily wants, and from the praises which impart to them enhanced energy and augmented power: there is nothing, however, which denotes any particular potency in the prayer or hymn, so as to compel the gods to comply with the desires of the worshipper; nothing of that enforced necessity which makes so conspicuous and characteristic a figure in the Hindu mythology of a later date, by which the performance of austerities for a continued period constrains the gods to grant the desired boon, although fraught with peril and even destruction to themselves." (Wilson, 'R'igveda,' vol. i. p. xxiii, ff.)

If we ask what divinities were worshipped by the authors of the R'igveda hymns, an answer is given by Yâska, the oldest Vaidik exegote of those whose writings are preserved, in the following manner:—"The Vaidik exegote says that there are *three* Devatâs, viz., Agni, who resides on earth; Vâyu, or Indra, who resides in the intermediate region (between heaven and earth); and Sûrya, who resides in heaven. Because each of these Devatâs has a variety of attributes, there are indeed many names of them" (vii. 5); and "of the Devatâ there is but one soul; but the Devatâ having a variety of attributes, it is praised in many ways: other gods are merely portions of the one soul" (vii. 4). The Anukraman'î, or explanatory index to this Veda, says, in a similar manner, "The deities are only three, whose places are the earth, the intermediate region, and heaven: (namely) fire, air, and the sun. They are pronounced to be (the deities of the mysterious names severally); and (Prajâpati) the lord of creation is (the deity) of them collectively. The syllable *Om* intends every deity; it belongs to (Paramesht'h'i) him who dwells in the supreme abode; it appertains to (Brahman) the vast one; to (Deva) God; to (Adhyâtman) the superintending soul. Other deities belonging to those several regions are portions of the three gods; for they are variously named and described, on account of their various operations: but (in fact) there is only one deity, the *Great Soul* (Mahânâtmâ). He is called the Sun; for he is the soul of all beings: (and) that is declared by the sage: 'the sun is the soul of (jagat) what moves and of (tasthivat) that which is fixed.' Other deities are portions of him." (Colebrooke, 'Misc. Ess.,' i. p. 27.)

If we took this account for a correct representation of the Vaidik creed we could not but draw the inference that it was based on the belief in one god, or, at least, one principle of creation, and that the many gods met with in the Vaidik hymns are merely poetical allegories of the One Great Soul. We have quoted indeed, before, a mystical hymn of the R'igveda, which would seem to countenance this view. But an unbiassed examination of the R'igveda poetry must lead to the conclusion that religion did not take this course in India; that we must distinguish between one or more hymns, evidently the product of a later and philosophical age, and the bulk of that collection which contains nothing but the adoration of the elementary powers in their various manifestations and degrees. Nor can we give an unqualified assent to the threefold classification of the Vaidik divinities, as given by Yâska, and repeated by the Anukraman'î; for neither is Agni's abode restricted to earth, nor could Indra be identified or placed on the same level with Vâyu, nor would it be correct to assign to Sûrya such a place in the Vaidik pantheon as would equalise his rank with that of Agni or Indra. The real position and quality of the *principal* Vaidik divinities of the R'igveda is, in short, this:—The chief deities are *Agni* and *Indra*, the two gods, as we have noticed before, to whom the first series of hymns is addressed in eight out of the ten Man'd'alas of the Sanhitâ. *Agni* (from *aj*, "to move," Latin, *igni*-) is the God of Fire, under a threefold aspect of this element: as it exists on earth, in its daily use and in its sacrificial capacity, as well as the heat of digestion and the principle of animal and vegetable life; secondly, as the fire of lightning; and thirdly, as the fire of the sun. Agni is praised therefore as the originator of the sacrifice, and as the mediator between gods and men: he conveys offerings to the former, and brings the gods to the worshipper. During the night he protects mortals from the demons who haunt the altars and are hostile to religious rites. On the other hand, as the fire of lightning, Agni is the "son, or the grandson, of the waters;" and as the fire of the sun he grants wealth, food, health, and life, destroys and revives all things. Not many subordinate divinities are mentioned in his train; sometimes the *Maruts*, or Winds, are, but they are more frequently the attendants of Indra; and the *Âpris*, female divinities, which also include insensible objects, such as the doors of the sacrificial hall. The proper offering to Agni is *ghee* (ghrita), or clarified butter.

Indra (a word of doubtful etymology, probably from an obsolete radical *id* or *ind*, "to see" or "to know") is the powerful god of the firmament. He bestows blessings and riches when propitiated by the juice of the Soma-plant, which is his appropriate offering. He has elevated the sun and fixed the constellations in the sky; but above all he is the conqueror of *Vr'itra* ("the enveloper"), the demon who hides the sun, and of the clouds which threaten to withhold their waters from the earth; he pierces them with his thunderbolt and the waters are let down. He is also represented as discovering, and rescuing with his thunderbolt, the cows which had been stolen and were hidden in the hollows of the mountains by a demon named Pan'i or Vala. It is possible that these cows, as Professor Whitney believes ('Journal Amer. Or. Soc.' iii. p. 320), are meant for an allegory of the reservoirs of water which are freed by Indra, like the waters in the myth of Vr'itra; but it is possible also that this legend is merely a poetical record of an occurrence of pastoral life, such as we frequently meet with in the R'igveda poetry. A subordinate class of gods who are naturally associated with Indra, are the *Maruts*, or Winds; they assist Indra in his battles with Vr'itra and the production of rain. "They ride on spotted stags, wear shining armour, and carry spears in their hands; no one knows whither they come nor whither they go, their voice is heard aloud as they come rushing on; the earth trembles and the mountains shake' before them. They are called the sons of *Rudra*, who is conceived of as peculiar god of the tempest." (Ib. p. 315.) Besides them a god of wind, *Vâyu*, is named: "he drives a thousand steeds; his breath chases away the demons; he comes in the earliest morning, as the first breath of air that stirs itself at day break, to drink the Soma, and the Auroras weave for him shining garments." This god is sometimes identified with Indra; but there are verses in which both, Indra and Vâyu, are invoked conjointly to share in the sacrifice.

Amongst the gods assigned by Yâska to the sphere of heaven, we have to notice in the first rank the *Adityas*, or the sons of the *Aditi*. The latter word means "indestructibility," and the Adityas are discribed as "elevated above all imperfection; they do not sleep or wink; their character is all truth; they hate and punish guilt; to preserve mortals from sin is their highest office." One of these Adityas, is *Sûrya*, the sun, who is described as driving a chariot drawn by seven golden steeds, and is also personified as the ornamented bird of heaven.

But he does not occupy that prominent rank among Vaidik gods which we might expect, and which seems to be allowed to him by Yâska. It must be observed, too, that some other words which mean "sun" in classical Sanskrit, especially *Savitr'i*, *Pûshan*, and *Aryaman* are likewise Âdityas in Vaidik mythology; and that *Vishn'u* also is an Âditya when he is identified with the sun in its three stages of rise, culmination, and setting ('R'igveda,' i. 22,17). Of other Âdityas moreover we point out *Varun'a* (from *vr'i* "to surround,"—Greek, Οὐρανο). He is the "all-embracing heaven, the orderer and ruler of the universe; he established the eternal laws which govern the movements of the world, and which neither immortal nor mortal may break; he regulated the seasons; appointed sun, moon, stars, and their courses; gave to each creature that which is peculiarly characteristic .... From his station in heaven Varun'a sees and hears everything, nothing can remain hidden from him." He is said to be the divinity presiding over the night, to support the light on high, and to make wide the path of the sun: he grants wealth, averts evil, and protects cattle. He is frequently invoked, together with *Mitra*, another Âditya, who is the divinity presiding over the day, and a dispenser of water. (Wilson, 'R'igveda,' i. p. xxxiv.)

The adoration of the sun is naturally connected with that of *Ushas*, "dawn," or rather of *Ushasas*, "many dawns." "She is addressed as a virgin in glittering robes, who chases away the darkness, ... who prepares a path for the sun, is the signal of the sacrifice, rouses all beings from slumber, gives sight to the darkened, power of motion to the prostrate and helpless." (Whitney, 'Journal Amer. Or. Soc.,' iii. p. 322.)

The last divinities which deserve our special attention are the two *As'wins*. They are the sons of the sea, and are represented as ever young and handsome, travelling in a golden, three-wheeled, triangular chariot, drawn by an ass or two horses, and the precursors of the dawn. They are called *Dasras*, "destroyers of fever or of diseases," for they are the physicians of the gods, and *Nâsatyas*, "never untrue." Many legends are connected with their career: they brought back to a father his lost child, they restored the blind to sight; they relieved one man of his old body by giving him a new one instead; they supplied another with a metal leg to replace the one he had lost in battle; they assisted seafarers in their perils, and so on. They are probably the two luminous points which precede the dawn; some compare them with the Dioscuri of the Greek.

The constellations are never named as objects of worship, and although the moon appears to be occasionally intended under the name *Soma*, particularly when spoken of as scattering darkness, yet the name and the adoration are in a much less equivocal manner applied to the Soma-plant. (Wilson, 'R'igveda,' i. p. xxvi.)

The great gulf which lies between this elementary worship of the R'igveda and the later mythology need not be pointed out; but it will not be without interest to observe that we already meet in its poetry with some of those names which assume so different a character in the epic poems and the Puran'as. Thus Rudra, the father of the Winds, becomes in the later mythology another name for S'iva, who is unknown to the Vaidik hymns. Their Vishn'u, a name of the Sun, and one of the Âdityas, is the second person of the later Hindu triad; and his epithet Trivikrama, or "he who takes three steps," which means, as we have seen, the sun in its three stages, gives rise to the myth of the fourth Avatâra of Vishn'u, when, as a dwarf, he strides over the three worlds—earth, intermediate space, and heaven—and compels Bali, who threatened the sovereignty of Indra, to seek refuge in Tartarus.

From the nature of this worship, and from the desire for food, cattle, and the like, so frequently expressed in the hymns, it has sometimes been inferred that the condition of life as depicted in these hymns was that of a nomadic and pastoral people. There can be nothing more erroneous, if we look upon the actual collection of the hymns as a whole; as we did—and in the present state of Sanskrit philology are compelled to do—when drawing the previous sketch of the ancient Hindu belief. This collection, on the contrary, gives abundant proof that the Hindus of the R'igveda were settled in villages and towns, that they were a manufacturing people; for weaving, the melting of metallic substances, the fabrication of golden and iron mails, of ornaments, and the like, are not unfrequently alluded to. It is remarkable also that they were a seafaring and a mercantile people. Even a naval expedition against a foreign island is mentioned in a hymn (i. 116, 3). Tugra, a friend of the As'wins, we are told, "sent (his son) Bhujyu to sea, as a dying man parts with his riches; but you (As'wins) brought him back in vessels of your own, floating over the ocean, and keeping out the waters. Three nights and three days, Nâsatyar, have you conveyed Bhujyu in three rapid revolving cars, having a hundred wheels, and drawn by six horses, along the watery bed of the ocean to the shore of the sea. This exploit you achieved, As'wins, in the ocean, where there is nothing to give support, nothing to rest upon, nothing to cling to, that you brought Bhujyu, sailing in a hundred-oared ship, to his father's house." We find them in possession of musical instruments, practising medicine, computing the division of time to a minute extent; and there is sufficient evidence in the hymns to show that they had not merely laws of buying and selling, but even such complicated laws of inheritance as we meet with in the most advanced period of Hindu life. According to the latter, for instance, a son is the heir of the paternal property, to the exclusion of a daughter, as she transfers her property, by way of dower, to another family. But in default of a direct male heir, the son of a daughter may perform the funeral rites, or, what is equivalent, inherit the paternal property, provided that the daughter be *appointed* for such a purpose when given in marriage. (See Colebrooke's 'Digest,' 3. 161, and various authorities quoted in Goldstücker's 'Sanskrit Dictionary,' s.v. 'Aputrikâ.') The same law is laid down in the following verses of Rigv. iii. 31. 1. 2. (Wilson's translation):—"The sonless father regulating (the contract) refers to his grandson (the son) of his daughter, and relying on the efficiency of the rite, honours his (son-in-law) with valuable gifts; the father, trusting to the impregnation of the daughter, supports himself with a tranquil mind. (A son) born of the body, does not transfer (paternal) wealth to a sister; he has made (her) the receptacle of the embryo of the husband; if the parents procreate children (of either sex), one is the performer of holy acts, the other is to be enriched (with gifts)."

That so advanced a state of social life could not remain without its evils and vices is obvious; we find hymns which describe gambling, which speak of robbers and thieves, of secret births, of youths associating with courtesans.

This sketch of the religious and social condition of ancient India rests, as mentioned, on the supposition of the R'igveda-Sanhitâ having always been that which it is now—in fact, on the native theory of the eternity of the Veda. In the beginning we quoted some passages from the 'Purân'as' which show that these late productions of Hindu religion look upon all the Vedas as created by Brahmâ; but we also pointed out that the poets of the hymns are held even by the oldest authorities to be inspired seers, who received them from the deities. Mr. Muir, in one of the most interesting and elaborate works of Sanskrit philology, the 'Original Sanskrit Texts,' has given other and very copious proof that the doctrine of the eternity of the Veda pervaded the poetry and the philosophical reasoning of ancient and mediæval India; and we must content ourselves with referring for further detail to the third volume of this excellent record of the 'Original Texts.' It may suffice therefore to add that even the differences which exist between the various editions of the sacred texts were explained away by an ingenious theory. It says that "the Vaidik texts got lost in the several Pralayas, or destructions of the worlds; and since each Manwantara had its own revelation, which differed only in the expression, not in the sense of the Vaidik texts, the various versions represent these successive revelations, which were remembered through their excessive accomplishments by the R'ishis." ('Orig. Sansk. Texts,' iii. p. 231, 232.) In short, though according to this theory, a succession of revelations is admitted by the Hindu divines, they are conceived of as a reproduction of the first revelation, which comprised the whole bulk of the sacred text.

The utter improbability of an original contemporaneousness of all the hymns of the R'igveda is such that a theory founded on it would scarcely require a remark for the non-Brahmanic student of Hindu antiquity. In reading these hymns, such a student would not fail to perceive that some describe the most primitive features, and others—as we have shown—the most complicated mechanism of social life; that in some the first bud of religious life is perceptible, while others contain "the full-grown fruit of long experience in thought, or mark the end, not the beginning, of a phase of religious development.' In other words, he would perceive the gradual and historical growth of that oldest document of the Brahmanic creed, the R'igveda-Sanhitâ. But even the Brahmanic student could not remain indifferent to the fact, that the hymns themselves destroy this theory of the eternity of the Veda, built up, as it was, in a priestly and systematising age. There are passages, for instance, in which the R'ishis themselves describe themselves as composers or "fabricators" or "generators," not as "seers" of the hymns. "This hymn," we read in one, "has been *made* to the divine race by the sages." "Thus, O Indra," says another, "have the Gotamas *made* for thee pure hymns;" or, "desiring wealth, men have *fashioned* (lit. fabricated) for thee this hymn, as a skilful workman (fabricates) a car;" or, "thus have the Gr'itsamadas, desiring succour, *fashioned* (lit. fabricated) for thee a hymn, as men make roads;" or, "the sages *generated* a pure hymn and a prayer to Indra;" "Wise Agni Bâtavedas, I *generate* a hymn for thee, who receivest it with favour;" and so on in numerous other instances. (Muir, 'Orig. Sansk. Texts,' iii. pp. 128-140.)

In other hymns, says Mr. Muir (Ib. p. 117), "the .... passages from the R'igveda either expressly distinguish between contemporary R'ishis and those of a more ancient date, or, at any rate, make reference to the one or the other class. This recognition of a succession of R'ishis constitutes one of the *historical* elements in the Veda." If this succession were simply one of the poets, it might seem, from a Brahmanic point of view, to be not incompatible with the theory mentioned before; but it appears in conjunction with the narration of events, and thus excludes the possibility of their original coævity. "Those gods," we read, for instance, "who formerly grew through reverence, were altogether blameless. They caused the dawn to rise, and the sun to shine for Vâyu and the afflicted Manu;" or, "listen to S'yâvâswa pouring forth libations, in the same way as thou didst listen to Atri when he celebrated sacred rites." (Comp. Muir, 'Orig. Sansk. Texts,' iii. pp. 116-128.)

Whichever view, therefore, one takes, it is clear that there are periods in the arrangement of those thousand and twenty-eight hymns which form the present R'igveda-Sanhitâ, and that the growth of the religious and social life of ancient India cannot be fully understood until we have a knowledge of the relative age at least of these hymns, since their real date may perhaps for ever remain as much beyond the control of philological research as it has remained hitherto. In some cases the description of events or the allusion to institutions of a domestic or public kind, in others the character of the religious notions expressed and the detail of the rites explained, may lead to a surmise as to the chronological relation of certain hymns; but since the soundness of a criterion of this kind will more or less depend on personal feelings or views, a safer footing is obtained in those hymns where the R'ishi himself refers to a predecessor who is the poet of another hymn, or to events anterior to him, met with however in other portions of R'igveda poetry. For there it is possible at once to establish a relative order in time between such hymns. But as instances of this description are rare, the real burden of proof will probably always rest with the linguistic facts that may be gathered from the various hymns. They are the stubborn monuments which raise their heads above the confusion created by the systematising arrangement of later times. As yet, however, Sanskrit philology has done little or nothing to enable us to see clearly in the mist of the gradual development of the Vaidik age. It is struggling even at present to save the very meaning of the Vaidik words, as handed down to us by native scholarship, and the grammatical explanation of the Vaidik commentaries, from a conceit which strives to substitute its own fanciful notions for the traditional lore—the only real means we possess for understanding these ancient texts.

If now we turn to the Sanhitâs of the next two Vedas, our attention will be particularly engaged by the purpose for which they were collected, or, as observed before, for which they were either entirely, or for the most part, extracted from the R'igveda-Sanhitâ. This purpose, we stated, was a liturgic one. The verses of the Sâmaveda were intoned at those sacrificial acts which were performed with the juice of the Soma-plant. A short account of the manner in which the libations of this juice were prepared and offered to the gods is given in the introduction of Stevenson's translation of the Sâmaveda. "The first thing to be done is to collect the Soma, or moon-plant, and the aran'i-wood for kindling the sacred fire; and this must be done in a moonlight night, and from the table-land on the top of a mountain. The moon-plants must be plucked up from the roots, not cut down; and after being stripped of their leaves, the bare stems are to be laid on a cart drawn by two rams or he-goats, and by them to be brought to the house of the Yajamâna, the institutor of the sacrifice, for whose especial benefit, and at whose expense, all the ceremonies are performed. The stems of the plants are now deposited in the hall of oblation . . . . bruised by the Brahmans with stones, and then put between two planks of wood, that they may be thoroughly squeezed and the juice expressed. The stalks, with their expressed juice, are then placed over a strainer made of goats' hair, sprinkled with water, and squeezed by the fingers of the officiating Brahmans, one or two of which must be adorned with flat gold-rings. The juice, mixed with water, now makes its way through the strainer and drops into the Dron'a Kalasa, the receiving vessel placed below, and situated at that part of the Yajnavedi (or sacrificial ground), called the Yoni, or womb . . . . The juice, already diluted with water, is in the Dron'a Kalasa further mixed with barley, clarified butter, and the flour of a grain called by the Marathas *wari*, the Sanskrit names of which are *nivâra* and *tr'in'adhânya*. It is now allowed to ferment till a spirit is formed, after which it is drawn off for oblations to the gods in a scoop called *sruch*, and in the ladle called *chamasa*, for consumption by the officiating Brahmans. The vessel, scoop, and ladle, are all made of the wood of the catechu-tree (*Mimosa catechu*). Nine days are mentioned in the Bhâshya as required for the purificatory rites . . . . There are three oblations offered daily; one early in the morning, one at noon, and one at night."

The sacrifices at which such oblations were offered are very numerous. The principal one seems to have been the *Jyotisht'oma*, a great sacrifice, which, if complete, consisted of seven *sansthâs* or stages, each occupying the space of several days. The Mîmânsists, however, probably yielding to the necessity of circumstances, consider the *Agnisht'oma* only, the first stage of the Jyotisht'oma, as obligatory for the performance of this rite; while they look upon the six others—the Atyagnisht'oma, Ukthya, Shod'as'in, Atirâtra, Aptoryâma, and Vâjapeya—as voluntary and supererogatory. "The Soma offering," says Dr. Windischmann, in his 'Dissertation on the Soma worship of the Arians,' "was unquestionably the greatest and the holiest offering of the ancient Indian worship. The sound of the trickling juice is regarded as a sacred hymn. The gods drink the offered beverage; they long for it (as it does for them); they are nourished by it, and thrown into a joyous intoxication: this is the case with Indra (who performs his great deeds under its influence), with the As'wins, the Maruts, and Agni. The beverage is divine, it purifies, it inspires greater joy than alcohol, it intoxicates S'ukra, it is a water of life, protects and nourishes, gives health and immortality, prepares the way to heaven, destroys enemies, &c. The Sâmaveda distinguishes two kinds of Soma, the green and the yellow; but it is the golden colour which is for the most part celebrated." (Muir, 'Orig. Sansk. Texts,' iii. p. 471.)

And these exhilarating and inebriating properties of the plant, divested from their poetical association with the gods, sufficiently explain the religious awe in which they were held by a people which learnt to experience their influence, and ascribed them to some mysterious cause.

Having explained before that the Sâmaveda verses are entirely taken from the R'igveda-Sanhitâ, we may now show the artificial manner in which these extracts were brought together for the purpose described, and how little value they possess as a poetical anthology. The Sanhitâ of the Sâmaveda consists of two separate portions. The first, called *Ârchika*, or *Chhandograntha*, is composed of five hundred and eighty-five verses; the second, called *Staubhika*, or *Uttarâgrantha*, contains twelve hundred and twenty-five verses. The verses of the first are arranged into fifty-nine *Das'ati*, or decades, subdivided again into *Prapât'hakas*, or chapters, with another subdivision into *Ardhaprapât'hakas*, or half-chapters. The second portion is also divided into *Prapât'hakas* with *Ardhaprapât'hakas*; these however are for the most part arranged according to triplets of verses, the first of which is already contained in the Archika portion, and thus appears twice in the Sâmaveda-Sanhitâ. This first verse is called the *Yoni*-verse, or the womb-verse, that in which the two others—the *Uttarâs*—are generated, because all the modifications which take place during the intonation of the former—the modulations, disruptions of letters, stoppages, &c.—must be likewise observed at the chanting of the latter. These modifications are taught in the Gânas, or song-books, the *Veyagâna* and *Âran'yagâna*, which contain the composition of the Ârchika, and the *Ûhagâna* and *Ûhyagâna*, which comprise that of the Staubhika. In the Ârchika portion, the verses of the R'igveda are nearly always disjoined from the connection in which they originally stood, while a somewhat greater continuity of extracts is observed in the Staubhika. In a very valuable synopsis given by Professor Whitney (in the second volume of Professor Weber's 'Indische Studien'), it is shown in what proportion these extracts were made from the R'igveda; it enables the student moreover, by comparing both collections, to ascertain that the compilers of the Sâmaveda completely lost sight of the original nature of the R'igveda hymns, and of their poetical worth; that no respect was paid to the integrity of the poets' thoughts, or to the motives which called forth their lays. Still, however inferior the collection of the Sâmaveda is to that of the R'igveda, so powerful is the poetical greatness of the principal Veda, that it could not be entirely destroyed, even in the garbled assemblage of its verses in the Sâmaveda.

But even this mite of æsthetical praise can scarcely be bestowed on the *Yajurveda-Sanhitâ*. Like the Sâmaveda, it also is a liturgic book: it also has largely drawn on the R'igveda hymns. But the first difference we observe is that its contents are not entirely taken from the principal Veda, and the second is marked by the circumstance that it often combines with verses passages in prose, which are called *yajus* (lit. "that by which the sacrifice is effected"), and have given to the Yajurveda its name. Besides, the ceremonial for which this Veda was made up is much more diversified and elaborate than that of the Sâmaveda, and the mystical and philosophical allusions which now and then appear in the R'igveda, probably in its latest portions, assume a more prominent place in the Yajurveda. In one word, it is *the* sacrificial Veda, as its name indicates. Hence we understand why it was looked upon in that period of Hindu civilisation which was engrossed by superstitions and rites, as the principal Veda, superior in fact to the R'igveda, where there is no system of rites. To Sâyan'a, for instance, the great commentator of the Vedas, who lived only four centuries ago, the poetry of the R'igveda, and even the collection of the Sâmaveda, are of far less importance than the Yajurveda. "The R'igveda and Sâmaveda," he says, in his introduction to the Taittirîya-Sanhitâ, "are like fresco-paintings, whereas the Yajurveda is the wall on which they stand" (Müller, 'Anc. Sansk. Lit.' p. 175); and it is on the ritual works connected with the oldest recension of this Veda that the speculations of the Mîmânsists, who refer their doctrine to the Sûtras of Jaimini, are based. (Goldstücker, 'Pân'ini,' p. 9.)

There is one remarkable fact to be noticed in the history of this Veda, which has no parallel in that of the other Vedas, a schism to which its collection gave rise, and which ended in the putting forth of two Yajurveda texts, the one assuming the name of the Black, the other that of the White Yajurveda. The Vishn'u-Purân'a, iii. 5. 2 (and nearly in the same manner the Vâyu-Purân'a), contain the following legend concerning the origin of this schism: "Yâjnavalkya, son of Brahmarâti, was Vais'ampâyana's disciple, eminently versed in duty and obedient to his teacher. An agreement had formerly been made by the Munis, that any one of their number who should fail to attend at an assembly on Mount Meru on a certain day should incur the guilt of Brahmanicide within a period of seven nights. Vais'ampâyana was the only person who infringed this agreement, and he in consequence occasioned the death of his sister's child, by touching it with his foot. He then desired all his disciples to perform in his behalf an expiation which should take away his guilt, and forbade any hesitation. Yâjnavatkya then said to him, "Reverend sir, what is the necessity for these faint and feeble Brahmans? *I* will perform the expiation." The wise teacher, incensed, replied to Yâjnavalkya, "Contemner of Brahmans, give up all that thou hast learnt from me; I have no need of a disobedient disciple, who, like thee, stigmatises these eminent Brahmans as feeble." Yâjnavalkya rejoined, "It was from devotion (to thee) that I said what I did; but I, too, have done with thee; here is all that I have learnt from thee." Having spoken, he vomited forth the identical Yajus texts tainted with blood, and giving them to his master, he departed at his will. The other pupils having then become transformed into partridges (*tittiri*) picked up the Yajus texts, and were thence called Taittirîyas. And those who had by their teacher's command performed the expiation, were from this performance (*charan'a*) called Charakâdhwaryus. Yâjnavalkya then, who was habituated to the exercise of suppressing his breath, devoutly hymned the sun, desiring to obtain Yajus texts. [The hymn follows.]

Thus celebrated with these and other praises, the sun assumed the form of a horse, and said, "Ask whatever boon thou desirest." Yâjnavalkya then, prostrating himself before the lord of the day, replied, "Give me such Yajus texts as my teacher does not possess." Thus supplicated, the sun gave him the Yajus texts called *Ayâtayâma*, which were not known to his master. Those by whom these texts were studied were called Vâjins, because the sun (when he gave them) assumed the shape of a horse (vâjin)." (Muir, 'Orig. Sansk. Texts,' iii. pp. 32, 33.)

However absurd this legend may be conceived to be, the two recensions of the Yajurveda which are preserved, plainly bear out the fact, that the "White" Yajurveda is more recent than the "Black," and that the former is evidently intended as an improvement of the latter —whence it is but reasonable to infer that such an infringement on an existing text cannot have taken place without some, and probably a great, conflict between the followers of the one and the originators of the other. To understand, however, the nature of this improvement, we must advert to the character of the older text.

It has been stated before, that each Veda consists of a collection of hymns—the Sanhitâ portion—and of a Brâhman'a portion, which is especially intended for the explanation of the rites at the performance of which the hymns were employed. This division is maintained in its purity so far as the R'ig- and Sâma-veda are concerned. It is greatly obscured, however, in the Taittirîya-Sanhitâ, or that of the "Black" Yajur-veda. There, verses and description of ritual occur promiscuously; it is in reality a text-book for the guidance of the Adhwaryu priest, while the Hotr'i and Udgâtri had to study their special ritual books, in order to know when any particular verse of their Sanhitâs ought to come in at a certain rite. This motley character of the Taittirîya-Sanhitâ is probably indicated by the epithet "Black," or "Dark," which is given to the oldest recension of the Yajurveda; and though the Tittiris may be a real proper name, the meaning of this word being "partridge," it is not impossible that this coincidence suggested the etymological legend mentioned above. Now, the impurity of this text, as intimated by the legend, its "darkness," as it were, is removed in the "White" Yajurveda, which is ascribed to the R'ishi Yâjnavalkya; for in the latter we possess a "clear" Sanhitâ and a "clear" Brâhman'a.

The topics treated of in both redactions are on the whole the same, but they are differently placed, and vary sometimes in detail. The *As'wamedha* or horse sacrifice, which is merely alluded to in a few hymns of the R'igveda-Sanhitâ, is dwelt upon in the Yajurveda with considerable detail. The fact of six hundred and nine animals of various descriptions, domestic and wild, including birds and reptiles, being tied to twenty-one posts, and the intervals between them, at the performance of this sacrifice, may convey an idea of the complicated ritual which existed at the time when this Veda was composed. Of ceremonies, unknown to the other Vedas, we may mention also, the *Purusha-medha* or man-sacrifice—an emblematic ceremony, in which a hundred and eighty-five men of various specified tribes, characters, and professions, are bound to eleven posts, and consecrated to various deities—the *Sarva-medha* or all-sacrifice, and the *Pitri-medha* or sacrifice to the manes. It is worthy of notice, too, not only that all the four castes, the institution of which cannot with certainty be traced to the period of the R'igveda-Sanhitâ, make their distinct appearance in the Yajurveda, but also that it contains many words which in the mythology of the epic poems and the Purân'as are names of S'iva, the third god of the later Hindu triad.

The Taittirîya-Sanhitâ of the Black Yajurveda is arranged in seven *Kân'd'a* or books, with forty-four *Prapât'haka* or chapters, containing altogether six hundred and fifty-one *Anuvâka* or sections, divided into two thousand one hundred and ninety-eight *Kan'd'ikâ* or portions. The *Vâjasaneyi-Sanhitâ* of the White Yajurveda, in the Mâdhyandina recension, is divided into forty *Adhyâya* or lectures, with three hundred and three *Anuvâka* or sections, comprising one thousand nine hundred and seventy-five *Kan'd'ikâ* or portions. Other schools connected with either form of this Veda adopted other divisions, which, however, need not be adverted to here.

That the *Sanhitâ* of the *Atharvaveda* is not a sacrificial collection in the sense of that of the Samâ- and Yajur-veda we have explained already. It is divided into twenty *Kân'd'a* or books, the first eighteen of which contain thirty-four *Prapât'haka* or chapters, which comprise ninety-four *Anuvâka* or sections: the seventeenth Kân'd'a consisting of one Prapât'haka only, which has no further subdivision; the nineteenth Kân'd'a is not divided into Prapât hakas, but simply into seven Anuvâkas; and the twentieth contains nine Anuvâkas, the third of which has three *Paryâyas*. The Anuvâkas in their turn consist of about six thousand verses. "Its first eighteen books," of which alone it was originally composed, Professor Whitney, the learned editor of the 'Atharvasanhitâ,' observes ('Journal of the American Oriental Society,' vol. iv. p. 254), "are arranged upon a like system throughout: the length of the hymns, and not either their subject or their alleged authorship, being the guiding principle; those of about the same number of verses are combined together into books, and the books made up of the shorter hymns stand first in order. A sixth of the mass, however, is not metrical, but consists of longer or shorter prose pieces, nearly akin in point of language and style to passages of the Brâhman'as. Of the remainder, or metrical portion, about one-sixth is also found amongst the hymns of the R'ik, and mostly in the tenth book of the latter; the rest is peculiar to the Atharva. Respecting their authorship the tradition has no information of value to give; they are with few exceptions attributed to mythical personages.

"As to the internal character of the Atharva hymns, it may be said of them, as of the tenth book of the R'ik, that they are the productions of another and a later period, and the expressions of a different spirit, from that of the earlier hymns in the other Veda. In the latter, the gods are approached with reverential awe, indeed, but with love and confidence also; a worship is paid them that exalts the offerer of it; the demons, embraced under the general name *Rakshas*, are objects of horror, whom the gods ward off and destroy; the divinities of the Atharva are regarded rather with a kind of cringing fear, as powers whose wrath is to be deprecated and whose favour curried for; it knows a whole host of imps and hobgoblins, in ranks and classes, and addresses itself to them directly, offering them homage to induce them to abstain from doing harm. The *mantra*, prayer, which in the older Veda is the instrument of devotion, is here rather the tool of superstition; it wrings from the unwilling hands of the gods the favours which of old their good-will to men induced them to grant, or by simple magical power obtains the fulfilment of the utterer's wishes. The most prominent characteristic feature of the Atharva is the multitude of incantations which it contains; these are pronounced either by the person who is himself to be benefited, or, more often, by the sorcerer for him, and are directed to the procuring of the greatest variety of desirable ends; most frequently, perhaps, long life, or recovery from grievous sickness, is the object sought; then a talisman, such as a necklace, is sometimes given, or in very numerous cases some plant endowed with marvellous virtues is to be the immediate external means of the cure; farther, the attainment of wealth or power is aimed at, the downfall of enemies, success in love or in play, the removal of petty pests, and so on, even down to the growth of hair on a bald pate. There are hymns, too, in which a single rite or ceremony is taken up and exalted, somewhat in the same strain as the Soma in the Pâvamânya hymns of the R'ik. Others of a speculative mystical character are not wanting; yet their number is not so great as might naturally be expected, considering the development which the Hindu religion received in the periods following after that of the primitive Veda. It seems in the main that the Atharva is of popular rather than of priestly origin; that in making the transition from the Vedic to modern times, it forms an intermediate step, rather to the gross idolatries and superstitions of the ignorant mass, than to the sublimated pantheism of the Brahmans." (Ib. vol. iii. p. 307.)

The general character of the *Brâhman'a*, or dogmatic, portion of the Vedas having been explained before, a short notice of the principal works of that class, and a few extracts from them, will illustrate the position they hold between the collection of hymns and the remainder of the Vaidik literature.

The Brâhman'a of the Bahvr'ichas, or the priests of the R'igveda, is still preserved in two editions. The former—the *Aitareya-Brâhman'a*—consists of eight *Panchikâ* or pentades of *Adhyâyas*, thus comprising forty Adhyâyas or lectures, which again are subdivided into two hundred and eighty-five *Khan'd'a* or portions. The latter, the *S'ânkhâyana-Brâhman'a*, which bears also the name of the *Kaushîtaki-Brâhman'a*, consists of thirty Adhyâyas, likewise subdivided into a number of Khan'd'as. Both Brâhman'as contain on the whole the same matter; but the difference of the manner in which their subjects are arranged and treated leads to the supposition that the first thirty lectures of the Aitareya-Brâhman'a are older than those of the S'ânkhâyana, whereas the last ten lectures of the former contain rites not explained in the latter, and are probably therefore more recent than the S'ânkhâyana. These Brâhman'as do not follow the order of the hymns of the R'igveda-Sanhitâ, but quote them as they would be required by the Hotr'i priest for the performance of the rites described. In order to give an idea of the elaborate ceremonial which called these Brâhman'a into life, and of the mysticism which connects them with a subsequent class of works, we will first give an abstract of an important ceremony, treated of with great detail in the last books of the Aitareya-Brâhman'a, and several times alluded to in the epic poetry of the Mahâbhârata and Râmâyan'a,—the *Abhisheka* or inauguration of a king.

This ceremony is either part of a Râjasûya, and performed by a king at the end of this sacrifice, or it is not part of a sacrifice, and then occurs at a king's accession to the throne. For celebrating the former ceremony there must have been prepared a throne-seat of the wood of the *udumbara* (*Ficus glomerata*), resting on four legs a span high, with boards placed on them, and side-boards of the dimensions of a cubit or two spans; the whole well fastened together with a texture made of cords of *munja* grass (*Saccharum Munja*); a tiger skin, which is placed on the seat with the hair upward and the neck to the east, a large four-cornered ladle of *udumbara* wood, and a branch of the same. In the ladle have been put eight things: curd, honey, clarified butter, water proceeding from rain during sunshine, before it has fallen down, blades of *S'yâma* grass, sprouts, spirituous liquor, and *Du'b* grass (*Panicum dactylon*). To prepare a site for the throne three lines have been drawn on a place of sacrifice . . . . one southwards, another westwards, and a third northwards; the one to the south is that on which the throne is to be placed, with its front towards the east, so that the two feet to the north come to stand within the *Vedi* or sacrificial ground, and the two to the south without; this latter spot occupied by the throne seat, is called *S'rî* (comm., as a type of happiness or prosperity). The place within the *Vedi* being small, but that without being illimited, this portion of the throne indicates that the sacrificer may obtain definite and indefinite wishes within and without the *Vedi*. The tiger skin is the type of increase of military power, for the tiger is the hero of the wild beasts; the udumbara wood of the throne, ladle and branch, is the type of nourishing juice and of food (which the sacrificer is supposed to acquire by this symbol); curd, honey, and clarified butter typify the essence of water and plants (curd and butter, as the commentator observes, because they originate in grass and water, which are the food of cattle; honey, because it originates in the juice of plants collected by bees); water proceeding from rain during sunshine, before it has fallen down, typifies lustre (or energy); and rain (being the consequence of oblations to the gods) holiness; grass and sprouts typify food, hence prosperity and progeny; spirituous liquor is the type of a Kshatriya's power (comm., on account of its fierceness or hotness); Du'b grass (being the Kshatriya of the plants, and firmly established in the soil with its many roots) is the type of military power and of a firmly established rule. The principal features of the ceremony itself are the following. The king, who performs the sacrifice, kneels down at the back part of the throne-seat with his face to the east, and his right knee touching the ground. He then touches with his hands the throne-seat, and invites the gods to ascend it together with various metres—*Agni* with the metre Gâyatrî, *Savitr'i* with the Ushnih, *Soma* with the Anusht'ubh, *Br'ihaspati* with the Br'ihatî, *Mitra* and *Varun'a* with the Pankti, *Indra* with the Trisht'ubh, the *Vis'we Devâs* with the Jagatî—for the purpose of obtaining "kingly power, righteous government, increase of enjoyment, independent rule, attainment of more distinguished qualities than those possessed by other kings, coming (after death) into the world of Brahman, and obtaining there dominion, a mighty rule, mastership, independence, and a long residence there." The gods have arrived, and the king now ascends himself the throne-seat, first with his right and then with his left knee. The next ceremony is the propitiation of the liquid in the ladle, which is performed by the priest, who will pour it over the king by reciting these verses (from the Atharvaveda): "Waters, behold me with a favourable eye; with a favourable body touch my skin; all fires, for they reside in water, I invoke on your account; do you produce in me beauty, bodily strength, and energy;" and by the king repeating these words after him. If this propitiation did not take place, the liquid would destroy the vigour of the king. After this, the priest covers the head of the king with the udumbara branch, and pours the liquid over him while reciting the following three R'igveda verses: "These waters are most propitious; they have healing power to free from all disease; they are the augmenters of kingly power and its supporters; they are immortal." "With which Prajâpati (the lord of creatures) sprinkled Indra, the king Soma and Manu, with these I sprinkle thee, that thou becomest king of kings in this world." "The queen, thy mother, bore thee to be great amongst the great, and a righteous ruler over men; an auspicious mother bore thee." And this Yajurveda verse: "The divine Savitr'i has given his consent, therefore, I pour (this liquid) over thee with the arms of the As'wins (comm., not with my own), with the hands of Pûshan, with the beauty of Agni, with the radiance of Sûrya, and with the senses of Indra, for the sake of strength, prosperity, glory, and increase of food." After the recital of other verses, by which spirituous liquor and Soma are intended to become identified, the king drinks the liquor, and presents the rest to a friend. He then places the udumbara branch on the ground, and prepares himself for descending from the throne-seat; but while he is still seated, and puts his feet on the ground, he says: "I firmly stand on heaven and earth, I firmly stand on exhaled and inhaled air, I firmly stand on day and night, I firmly stand on food and drink; on what is Brâhman'a, on what is Kshatriya—on these three worlds stand I firmly!" He then descends, sits down on the ground with his face towards the east, utters thrice the words, "adoration to what is Brâhman'a!" and offers a gift (comm., a cow) to a Brâhman'a. The object of this gift is the attainment of victory in every quarter, and over every description of enemies; and his threefold expression of adoration to what is a Brâhman'a, implies that a kingdom prospers and has valiant men when it is under the control of the Brâhman'as, and that a valiant son will be born to him. Then the king rises, puts fuel into the sacrificial fire, and takes three steps to the east, north, and to the north-east, while reciting several verses specified. Upon this he sits down by the domestic fire, and the Adhwaryu priest makes for him, out of a goblet, four times three oblations, with clarified butter, to Indra, while reciting other R'igveda verses. "A king for whom these libations are made to Indra in the indicated manner, becomes free from disease, cannot be injured by enemies, is exempt from poverty, everywhere protected against danger, and thus becomes victorious in all the quarters, and, after death, established in Indra's heaven."

The rites of the Abhisheka ceremony, which are performed at a king's accession to the throne, are founded on the proceedings which are described as having taken place when Indra was consecrated by the gods as their supreme ruler. The latter are, as a matter of course, of an entirely mystical kind. Thus, the eight parts of his throne-seat are said to have consisted of Sâmaveda verses; of the threads of the texture which was to hold this structure together, those that went lengthwise were made of R'igveda-, and those that went crossways of Sâmaveda-, the intervals being Yajurveda-verses; the covering of the throne was the goddess of Glory, the pillow the goddess of Happiness; Savitr'i and Br'ihaspati supported the fore-legs, Vâyu and Pûshan the hind-legs, Mitra and Varun'a the two top-boards, and the two As'wins the two side-boards, of the throne-seat, &c. The inauguration of the mortal king begins with the priest calling upon him to take the following oath:—"If I (the king) do ever harm to thee, thou (the priest) mayst deprive me of all pious acts which I have done from the time of my birth up to that of my death, of heaven, and whatever else good has been accomplished by me, of long life and offspring." He then orders his attendants to bring four kinds of fruits: the fruit of the *Nyagrodha* (*Ficus Indica*), of the *Udumbara* (*Ficus glomerata*), of the *As'wattha* (*Ficus religiosa*), and of the *Plaksha* (*Ficus infectoria*); besides, four kinds of grain: rice with small grain, rice with large grain, *Priyangu*, and barley. Next they bring at his command a throne-seat of udumbara-wood (made in the manner as described before), a ladle of udumbara (or, instead of the latter, a vessel of udumbara), and an udumbara branch. Then they put the various kinds of fruit and grain in the ladle or vessel, and pour over them curds, honey, clarified butter, and water proceeding from rain during sunshine, before it has fallen down; afterwards, having placed the ladle or vessel on the ground, they address the throne-seat with a Mantra, which recalls the component parts of Indra's throne, and thus tends to identify both. Then the priest asks the king to ascend the throne-seat, inviting the Vasus, Rudras, Âdityas, and the other divinities which were invited by Indra at his inauguration to ascend his throne, with the same metres and songs, and for the same purposes. Upon this the relatives of the king proclaim his high qualities in the same words as the gods proclaimed the greatness of Indra; the priest recites a certain R'igveda verse, and, placing himself before the throne with his face towards the west, covers the head of the king with the udumbara branch, the leaves of which have been wetted, and with a gold Pavitra, and sprinkles him with the liquid (in the ladle or vessel) while reciting the three R'igveda verses, and the Yajurveda verse quoted above, and uttering the three sacred words *Bhûr*, *Bhuvar*, *Swar*. Lastly, he addresses the king with the prayer that the Vasus, the Rudras, and the other divinities who performed this ceremony for Indra in the east, south, &c., may severally do the same for him in thirty-one successive days, and to the same effect as they did it for him. Of the ingredients of the sacred liquid, the Nyagrodha, being, on account of its wide spread, the king of the trees, and rice with small grains, being among plants principally productive of strength, the fruit of the former and the grain of the latter are the type of the qualities of a Kshatra; the fruit of the udumbara and the grains of the Priyangu are the type of increase of enjoyment; the fruit of the As'wattha and rice with large grains, the type of righteous government; the fruit of the Plaksha, the type of independent rule and attainment of more distinguished qualities than those possessed by other kings; barley is the type of military commandership; curds, that of sharpness of the senses; honey, that of the essence of plants and trees; and water is the type of freedom from death, or that of long life (because it nourishes). The ceremony having been completed, the king has to make a present to the inaugurating priest, namely, a thousand nishkas of gold, a field, and cattle; but this amount seems merely to constitute a minimum acknowledgement of the exertions of the priest, for the text of the Aitareya-Brâhman'a adds that "they say, a king should give innumerable, illimited presents, since a king is illimited (in wealth), and thus will obtain illimited benefit to himself;" and it adds, too, several instances in which kings bestowed unbounded wealth on the officiating priests. After the priest has received the gift, he hands to the king a goblet of spirituous liquor in reciting an appropriate R'igveda hymn, which has the power of transforming the qualities of the liquor drunk by the king into those of the juice of the Soma-plant. Lastly, the king recites some other verses specified. (For a fuller account of this ceremony, compare Goldstücker's 'Sanskrit Dictionary,' s.v. 'Abhisheka.')

As an illustration of those passages of the Aitareya-Brâhman'a, which partake more of an incantatory nature, we may quote the description of a rite which occurs in its last chapter, and relates to rites to be performed, under the direction of a proper Purohita or chaplain, for the destruction of the king's enemies. "Foes, enemies, and rivals," we read there, "perish around him who is conversant with these rites. That which (moves) in the atmosphere is air (Brahman), around which perish five deities—lightning, rain, the moon, the sun, and fire. Lightning having flashed, disappears behind rain: it vanishes, and none knows (whither it is gone). When a man dies, he vanishes; and none knows (whither his soul is gone). Therefore, whenever lightning flashes, pronounce this prayer: 'May my enemy perish: may he disappear, and none know (where he is).' Soon, indeed, none will know (whither he is gone). Rain having fallen (evaporates and), disappears within the moon, &c. When rain ceases, pronounce this (prayer), &c. The moon at the conjunction, disappears within the sun, &c. When the moon is dark, pronounce, &c. The sun when setting, disappears in fire, &c. When the sun sets, pronounce, &c. Fire, ascending, disappears in air, &c. When fire is extinguished, pronounce, &c. These same deities are again produced from this very origin. Fire is born of air; for, urged with force by the breath, it increases. Viewing it, pronounce (this prayer), 'May fire be revived: but not my foe be reproduced; may he depart averted.' Therefore, does the enemy go far away. The sun is born of fire. Viewing it, say, 'May the sun rise, but not my foe be reproduced,' &c. . . . . . The observance (enjoined) to him (who undertakes these rites, is as follows): let him not sit down earlier than the foe; but stand while he thinks him standing. Let him not lie down earlier than the foe; but sit while he thinks him sitting. Let him not sleep earlier than the foe, but wake while he thinks him waking. Though his enemy had a head of stone, soon does he slay him: he does slay him." (Colebrooke, 'Misc. Ess.,' i. p. 45.)

The legends narrated in this, as well as in other Brâhman'as, intend always, as indicated before, to explain the origin of a rite, or to illustrate its efficacy. Among those met with in the Aitareya-Brâhman'a, we may point particularly to one, as it is remarkable in several respects. It had to be recited by the Hotr'i, sitting on a gold-embroidered carpet, to a king whose inauguration had been completed; and another priest, sitting on a similar carpet, had to repeat the words of the Hotr'i. But a victorious king is likewise recommended to have this legend recited to him, though he may not have performed the sacrifice; and a man desirous of progeny is promised the birth of a son if it is properly read to him. We mean the legend of *S'unah's'epa.* Its substance is as follows:—

Once upon a time there lived Haris'chandra, a son of Vedhas, and a descendant of Ikshwâku. Though he had a hundred wives, he did not obtain a son from them. His desire, however, of having one became still stronger than it was, when Parvata and Nârada visited him, and when Nârada explained to him the boons a man derives from being blessed with the birth of a son. Following the advice of Nârada, Haris'chandra addressed himself, therefore, to Varun'a, and promised the god to sacrifice him his son, if he granted him one. Varun'a assented to the offer. Now a son, who received the name of Rohita, being born to Haris'chandra, Varun'a presented himself, and claimed the fulfilment of the compact. But Haris'chandra said: "Cattle is fit for a sacrifice when it is ten days old; let him then become ten days old and I shall sacrifice him to thee." Varun'a assented; but the ten days having passed away, Haris'chandra again said: "Cattle is fit for a sacrifice when it has got teeth; let him then get teeth, and I shall sacrifice him to thee." Once more Varun'a assented; but when Rohita had got his teeth, his father said to Varun'a: "Cattle is fit for a sacrifice when it loses again his teeth; let him then lose his teeth, and I shall sacrifice him to thee." Again Varun'a assented; but Rohita having lost his teeth, his father said to Varun'a: "Cattle is fit for a sacrifice when it recovers its teeth; let him then recover his teeth, and I shall sacrifice him to thee." Varun'a assented; but Rohita having recovered his teeth, his father said to Varun'a: "A warrior is fit for a sacrifice when he is able to use his weapon; let him then learn to use his weapon, and I shall sacrifice him to thee." Again Varun'a assented; and when Rohita knew how to use his weapon, his father said to him: "Varun'a, my son, has given thee to me, and I shall sacrifice thee to him." But Rohita refused, took his bow and went to the forest, where he wandered about during a whole year. Varun'a, however, now seized Haris'chandra, and made him swell. On hearing this, Rohita went about and met Indra, who encouraged him to wander first for another, then a third, a fourth, a fifth, and a sixth year.

At the end of this period he saw in the forest a R'ishi of the name of Ajîgarta, the son of Suyavasa, who lived there in great poverty with his three sons, *S'unaspuchchha, S'unah's'epa,* and *S'unolângula.* Rohita offered him a hundred cows if he gave up one of his sons to be sacrificed instead of him to Varun'a. Ajîgarta accepted the offer, but retained his oldest son; and his wife claiming the youngest, both agreed to give up S'unah's'epa. Rohita then took him to his father, Haris'chandra, and Varun'a also having confirmed the barter, since, he thought, a Brâhman'a is of greater value than a Kshatriya, Haris'chandra in celebrating the rite of the Râjasûya substituted S'unah's'epa for the victim to be immolated at this sacrifice. The Hotr'i priest who officiated at it was Vis'wâmitra, Jamadagni fulfilled the functions of the Adhwaryu, Vasisht'ha those of the Brahman, and Ayâsya those of the Udgatr'i. Yet the preliminary rites having being fulfilled, no one could be found who would tie S'unah's'epa to the sacrificial post. Upon which Ajîgarta offered to do this if they gave him another hundred of cows. They did so; but though S'unah's'epa now was tied to the post, no one would immolate him. Again Ajîgarta came forward and promised to immolate his son if they would give him a third hundred of cows. They did so, and Ajîgarta sharpened his knife and approached his son. Now S'unah's'epa resolved to implore the gods to release him. He addressed himself first to Prajâpati with an appropriate R'igveda hymn, but the god told him to pray to Agni. Agni, invoked with another hymn, told him to pray to Savitr'i; and Savitr'i told him to address Varun'a; but Varun'a sent him once more to Agni, who now recommended him to praise all the gods with an appropriate hymn. S'unah's'epa obeyed; his ties were released, and Haris'chandra was restored to health. S'unah's'epa, on his part, now instituted a new sacrifice. But when he placed himself at the side of Vis'wâmitra, and Ajîgarta claimed him back, Vis'wâmitra replied: "No, the gods (*devâs*) have given him (*arâsata*) to me;" and from that time (he was no longer S'unah's'epa, that is, Dogstail), but Devarâta (Θεοδοτος), the son of Vis'wâmitra. (For a literal and excellent translation of this legend by Professor Roth, see Weber's 'Indische Studien,' i. p. 458, ff.; and for some additional remarks, *ibid.*, ii. p. 112, ff.)

After these instances, which will convey an idea of the contents of the Brâhman'a in general, we must content ourselves with giving the names of the other *principal* works of this category. For, the difference which exists between them, however great, would be intelligible only if we could enter into the detail of the Vaidik rites, and into the growth of the legendary life which pervades this portion of the ancient literature of India.

Suffice it therefore to state that the Brâhman'a literature has found its greatest development in the train of that Veda which, as we might expect, would require more than any other Veda an explanation of the purposes for which it was formed—the Yajurveda. On the other hand, since the Sanhitâ of the Black Yajurveda is already a combination, as we have seen, of hymns and Brâhman'a, it is intelligible that we find in connection with the White Yajurveda that Brâhman'a which, though probably the most recent, still is the most systematic and the most complete of all the Brâhman'a. It is called the *S'atapatha-Brâhman'a*, and is ascribed, like the Sanhitâ of the White Yajurveda, to Yâjnavalkya. It is, like the Sanhitâ, preserved in the edition of the *Mâdhyandina* and in that of the *Kânwa* school. The former is divided into fourteen *Kân'd'a* or books, which contain one hundred *Adhyâya* or lectures; or into sixty-eight *Prapât'haka* (sections) with four hundred and thirty-eight *Brâhman'a*, and seven thousand six hundred and twenty-four *Kan'd'ikâ* (portions). In the *Kânwa* edition it comprises seventeen *Kân'd'a*, with a hundred and four *Adhyâya*, four hundred and forty-six *Brâhman'a*, and five thousand eight hundred and sixty-six *Kan'd'ikâ*. The first nine Kân'd'a of this Brâhman'a follow the first eighteen books of the Sanhitâ almost step for step, in quoting their verses and explaining their application at the sacrifices. The last five Kân'd'as, however, refer only partially—some even not at all—to the contents of the Sanhitâ, and may therefore be a later increase of this extensive Brâhman'a, which is extremely rich in antiquarian and mythological contents; but, on account of its purely ritual character, cannot be understood without the complete and excellent commentary of Sâyan'a.

The Brâhman'a of the Black Yajurveda is preserved in the school of the Taittirîyas, and bears the name of the Taittirîya-Brâhman'a, differing but little in character from its Sanhitâ.

As regards the Sâmaveda, Sâyan'a enumerates eight Brâhman'as connected with it, namely, the *Praud'ha* (also called *Tân'd'ya-* or *Panchavins'a*), the *Shad'vins'a*, the *Sâmavidhi*, *Ârsheya-Brâhman'a*, the *Devatâdhyâya-Brâhman'a*, and the *Upanishad*, which, according to Professor Müller ('Anc. Sansk. Lit.' p. 349) is probably the *Chhândogya-Upanishad*. The first two are the most important of these works, the Panchavins'a treating of the sacrifices which are performed with the juice of the Soma-plant, in rites which last from one to one hundred days. The *Sha'dvins'a* is remarkable on account of the incantatory ceremonies it describes; it ends with a chapter on omens and the rites to be performed on unlucky occasions, such as diseases, or at portentous occurrences, such as earthquakes, unusual phenomena, and the like.

The Brâhman'a of the Atharvaveda is the *Gopatha-Brâhman'a*. "That it was composed after the schism of the Charakas and Vâjasaneyins (the followers of the Black and White Yajurveda), and after the completion of the Vâjasaneyi-Sanhitâ, may be gathered from the fact that where the first lines of the other Vedas are quoted in the Gopatha, the first line of the Yajurveda is taken from the Vâjasaneyins, and not from the Taittirîyas. It is more explicit on the chapter of accidents than the Brâhman'as of the other Vedas . . . . The ceremonial in general is discussed in it in the same manner as in the other Brâhman'as." (Müller, 'Anc. Sansk. Lit.,' pp. 451, 452.)

The Sanhitâ or collection of Mantra, and the Brâhman'a, constitute that which is properly called the sacred literature of the Hindus, *the Veda;* they are also comprised under the name of *S'ruti* or revelation. But in speaking of the Veda we should not feel justified in leaving unnoticed that class of works, one portion of which is so intimately connected with it that it was held by later generations in the same awe as the Veda, whereas another portion has become so essential an appendage to it, that it was justly called Vedânga or "limb of the Veda."

The former category comprises the theological or theosophical writings, which have sprung from the Brâhman'a, and are perhaps more popular among European students than any other portion of the Vaidik literature—the *Upanishads.* The word *Upanishad* is rendered by the native dictionaries "mystery." *S'ankara*, the great Vedânta philosopher and glossator of the Upanishads, assumes that the word being derived from the radical *sad*,—with the prefixes *upa* and *ni*,—which amongst others has also the sense of "destroying," literally means the science which distroys erroneous ideas or ignorance. European scholars, on the contrary, have expressed the belief that it "means originally the art of sitting down near a teacher, of submissively listening to him" (from *upa* "below," *ni* "down," and *sad* "to sit" (for instance, Müller, 'Anc. Sansk. Lit.,' p. 319). But there is a strong probability that the word has been already used by a Hindu grammarian, who preceded the existence of the Upanishad works, in the sense of "secret" (Goldstücker, 'Pân'ini,' p. 141, note 164); and since this meaning is not incompatible with the etymology of the word—which may signify "entering into that which is hidden"—it seems certain that at no period the Upanishads were looked upon as mere lessons imparted to their pupils by old divines, but as the mysterious science which, through bestowing real knowledge on the human mind, leads to the attainment of eternal bliss.

For such is the object of all the Upanishads; and the knowledge they intend to convey is chiefly that of the production and nature of the world, of the properties of a Supreme Divinity, and of those of the human soul, which they conceive to be part of it. The same object is pursued, and the same views of the nature of the divine and the human soul as in the Upanishads are entertained by the Vedânta philosophy. We perceive therefore at once the close connection which exists between the Upanishads and this orthodox system of Hindu philosophy. Their difference, indeed, is merely that which separates the beginning from the end of a certain kind of philosophical reasoning. In the Vedânta the Hindu mind possesses a system which endeavours to deduct and to connect its ideas on the creation of the world, on the identity of the absolute and individual soul. Its method would not stand the test of *our* philosophical reasoning; but its explanations evidently aim at scientific precision and shortness of expression; and they are generally free from mythological mysticism. In the Upanishads, on the contrary, there is merely the material for a system of philosophy. The subject treated of by them is frequently dealt with in a desultory manner; it is intercepted by legends and allegories; it is adapted to the form of dialogues; it abounds in repetitions and verbose phraseology. But all these negative features of the Upanishads must be viewed in the mirror of the Hindu mind; and then we easily comprehend that, accessible to the popular understanding of the educated, they became the basis of that more enlightened belief which at all periods of Indian history has struggled against the idolatry and the gross practices produced by a misconception of the sacred texts, and doubtless also by the interested motives of a degenerated class of priests.

Within the circle of the Upanishad literature several periods are clearly distinguishable, though Sanskrit philology possesses no means of rendering them into intelligible dates. The first is that of the *Âran'yaka*. As the name indicates, and as it is explained by *Kâtyâyana* in one of his criticisms on the great grammarian *Pân'ini*, this class of Upanishads was studied in the solitude of the forests, apparently because it was thought necessary that the mind should divest itself from all contact with the world when meditating on the mysteries of life. These *Âran'yaka* are more immediately connected with the Brâhman'a than the Upanishads properly so called. The Br'ihad-Âran'yaka, for instance, is a part itself of the S'athapatha-Brâhman'a of the White Yajurveda; the Aitareya-Âran'yaka is added to the Aitareya-Brâhman'a, and the Chhândogya-Upanishad, as we have seen, though not bearing the name of an Âranyaka, is counted amongst the Brâhman'a of the Sâmaveda. These works combine their speculations with a considerable amount of legendary detail, in the same way as the Brâhman'a themselves; and they are held in especial respect on account of the obscure allusions in which they abound. A second class is much less burdened with mythological and allegorical detail; it is brief, and addresses itself more to the philosophical mind; it comprises the greater mass of the Upanishad literature, and is apparently more recent than the Âran'yaka. A third and last category is marked by the tendency it has to reconcile the doctrines of later sects with Vaidik theology; Upanishads belonging to it identify the universal Spirit with one or the other form of the gods of the Trimûrti, as it appears in sectarian belief. This latter description of Upanishads is chiefly connected with the Atharvaveda. We choose as an instance of the Âran'yaka class the following passages from the Aitareya-Âranya:—"This (world) verily was before (the creation of the world) soul alone, and nothing else whatsoever active (or non-active). He reflected: 'Let me create the worlds.' He created these worlds, namely, the sphere of water, the sphere of the sun-beams, the sphere of death, and the sphere of the waters. The sphere of water lies above the heavens, the heavens are its resting place; the sphere of the sunbeams is the atmosphere; the earth the world of death; the worlds which are beneath it, are the sphere of the waters. He reflected: These worlds indeed are created. Let me create the protectors of the world. Taking out from the waters a being of human shape, he formed him. He heated him (by the heat of his meditation). When he was thus heated, the mouth burst out as the egg (of a bird),—from the mouth speech,—from speech fire. The nostrils burst out,--from the nostrils breath,—from breath the wind. The eyes burst out,—from the eyes sight,—from the sight the sun. The ears burst out,—from the ears hearing,—from hearing the regions of space, &c. . . . . . . He reflected: Those worlds and protectors of the worlds (have been created). Let me now create food for them. He heated the waters (with the heat of his reflection). From them when heated, a being of organised form sprung forth; the form which sprung forth is verily food. When created it cried (by fear), and tried to flee. He (the first-born male) desired to seize it by speech. Had he seized it by speech (all) would be satisfied by pronouncing food. He desired to seize it by breath; he could not seize it by breathing. Had he taken it by breathing (all) would be satisfied by smelling food, &c. . . . . Of what nature is the *soul* which we worship by the words 'this soul,' and which of the two (the universal and individual) is the soul? (Are the instruments by which objects are perceived the soul, or the perceiver? No, not the instruments). Is it that by which the soul sees form, by which it hears sound, by which it apprehends smells, by which it expresses speech, by which it distinguishes what is of good, and what is not of good taste? The heart and the mind, knowledge about one's self, knowledge about one's power, the knowledge of the sixty-four sciences, the knowledge of what is practicable at this or another time, understanding of instruction, perception, endurance of pain, thinking, independence of mind, sensibility, recollection, determination, perseverance, desire, submission—all these are names of knowledge (as an attribute of the soul in its modification as life, of the inferior Brahman, not attributes of the supreme Brahman, which is of no form whatsoever). This soul is Brahman (the inferior Brahman), this Indra, this Prajâpati, this all gods and the five great elements and the light . . . . All this is brought to existence by knowledge, is founded on knowledge; the world is brought into existence by knowledge; knowledge itself is the foundation; Brahman is knowledge." (Rover's 'Translation of the Upan. Bibl. Ind.,' vol. xv. p. 28, ff.)

In the Br'ihad-Âran'yaka it is told that Janaka, the king of the Videhas, performed a sacrifice at which many Brahmans were assembled. The king having a great desire to know who among those Brahmans knew best the Vedas, tied a thousand cows in a stable, and covered the horns of each of them with ten pâda of gold. He then said to the pious men: "O venerable Brahmans, whoever amongst you is the best knower of Brahman shall drive home these cows." The Brahmans, however, did not venture to come forward. Then said Yâjnavalkya to his student: "Drive home those cows." But the Brahmans became angry, and began to examine the sage as to his knowledge of the Veda. "Then asked him Uddâlaka, the son of Arun'a," the legend continues, —"'Yâjnavalkya,' said he, 'in the country of the Madras we abode in the house of Pantchala, of the family of Kapi, for the sake of studying the science of offering. His wife was possessed by a Gandharva. We asked him (the Gandharva), 'Who art thou?' He said, 'Kabandha, the son of Atharvan'a.' He said to Patanchala, of the family of Kapi, and to (us) priests, 'O Kâpya, knowest thou that Thread by which this world, and the other world, and all beings are bound together?' Patanchala, of the family of Kapi, said, 'I do not know it, O Venerable.' He said to Pantanchala, and to (us) priests,—'Knowest thou, O Kâpya, that Inner Ruler who within rules this world, and the other world, and all beings?' Patanchala said,—'I do not know this, O Venerable.' He said to Patanchala, and to (us) priests,—'O Kâpya, whoever knows the Thread and the Inner Ruler, knows Brahman, knows the worlds, knows the gods, knows the Vedas, knows the elements, knows the soul,—knows all.' Then (the Gandharva) said (all about the Thread and the Inner Ruler) to them. 'Therefore do I know this. If thou, O Yâjnavalkya, ignorant of the Thread and the Inner Ruler, hast taken away the cows (destined for the best knower of Brahman), thy head will certainly drop down.' 'I know verily, Gautama, the Thread and the Inner Ruler.' 'Any one may say this, I know, I know, but tell the manner in which thou knowest.' He said,—'The wind, O Gautama, is the Thread; by the wind, as by a thread, are this world, the other world, all beings bound together, O Gautama. Therefore, O Gautama, it is said of a dead man, that his members are relaxed; for by the wind, O Gautama, as by a thread, they are bound together.' 'This is so, O Yâjnavalkya; now explain the Inner Ruler.' 'He who dwelling in the earth is within the earth, whom the earth does not know, whose body is the earth, who within rules the earth, is thy soul,—the Inner Ruler—immortal. He who dwelling in the waters is within the waters, whom the waters do not know, whose body are the waters, who within rules the waters, is thy soul,—the Inner Ruler—immortal. He who dwelling in the fire is within the fire, &c. . . . . he who dwelling in the atmosphere, &c. . . . . he who dwelling in the wind, &c. . . . . in the heavens, &c. . . . . in the sun, &c. . . . . in the regions of space, &c. . . . . in the moon and stars, &c. . . . . in the ether, &c. . . . . in the darkness, &c. . . . . in the light, &c. . . . . in all elements, &c. . . . . in the vital air, &c. . . . . in speech, &c. . . . . in the eye, &c. . . . . in the ear, &c. . . . . in the mind, &c. . . . . in the skin, &c. . . . . in knowledge, &c. . . . .; he who dwelling in the seed is within the seed, whom the seed does not know, whose body is the seed, who from within rules the seed, is thy soul—the Inner Ruler—immortal. Unseen, he sees; unheard, he hears; unminded, he minds; unknown, he knows. There is none that sees, but he; there is none that hears, but he; there is none that minds, but he; there is none that knows, but he. He is thy soul—the Inner Ruler—immortal. Whatever is different from him is perishable.'" (Ib., vol. ii. part iii., p. 199, ff.)

An Upanishad of the second class is, for instance, the I's'a-Upanishad, which derives an additional interest from the circumstance that it is the only Upanishad which forms part of a Sanhitâ itself, namely, of that of the White Yajurveda, and thus strengthens the proofs which may be alleged for the later recension of this Veda. It runs as follows: "Whatever exists in this world is to be enveloped by (the thought of) God (the Ruler). By renouncing the world, thou shalt save (thy soul). Do not covet the riches of any one. Performing sacred works, let a man desire to live a hundred years. If thou thus (desirest), O man, there is no other manner in which thou art not tainted by work. To the godless worlds, covered with gloomy darkness, go all the people, when departing (from this world), who are slayers of their souls. He (the soul) does not move, is swifter than the mind, not the gods (the senses) did obtain him, he was gone before. Standing, he outstrips all the other (gods, senses), how fast they run. Within him the ruler of the atmosphere upholds the vital actions. He moves, he does not move; he is far and also near; he is within this all, he is out of this all. Whoever beholds all beings in the soul alone, and the soul in all beings, does hence not look down (on any creature). When a man knows that all beings are even the soul, when he beholds the unity (of the soul), then there is no delusion, no grief. He is all-pervading, brilliant, without body, invulnerable, without muscles, pure, untainted by sin, he is allwise, the Ruler of the mind, above all beings, and self-existent. He distributed according to their nature the things for everlasting years. Those who worship ignorance, enter into gloomy darkness, into still greater darkness those who are devoted to knowledge. They say, different is the effect of knowledge, different the effect of ignorance; thus we heard from the sages who explained (both) to us. Whoever knows both, knowledge and ignorance together, overcomes death by ignorance, and enjoys immortality by knowledge. Those who worship uncreated nature, enter into gloomy darkness, into still greater darkness those who are devoted to created nature. They say, different is the effect from (worshipping) uncreated nature, different from (worshipping) created nature. This we heard from the sages who explained (both) to us. Whoever knows both, created nature and destruction together, overcomes death by destruction, and enjoys immortality by created nature. To me whose duty is truth, open, O Pûshan, the entrance to the truth concealed by the brilliant disk, in order to behold (thee). O Pûshan, R'ishi thou alone, O dispenser of justice (Yama), O Sun, offspring of Prajâpati, disperse thy rays (and) collect thy light; let me see thy most auspicious form; for the same soul which is in thee, am I. Let my vital spark obtain the immortal air; then let this body be consumed to ashes. *Om*. O my mind, remember, remember (thy) acts, O mind, remember, remember thy acts. Guide us, O Agni, by the road of bliss to enjoyment; (guide us), O God, who knowest all acts. Destroy our crooked sin, that we offer thee our best salutation." (Ib., vol. xv. p. 71.)

The principal Âran'yaka and Upanishads connected with each of the four Vedas are the following: to the R'igveda belong, the Aitareya-Âran'yaka and the Kaushîtaka-Âranyaka, the third book of which is the Kanshîtaky-Upanishad. The Upanishads of the Sâmaveda are the Chhândogya- and the Kena-Upanishad. To the Black Yajurveda belongs the Taittirîya-Âran'yaka, the four last books of which contain two Upanishads, namely, the Taittirîya- and the Nârâyan'îya-Upanishad; besides the Swetâs'watara-, Maitrâyan'a-, and Kât'haka-Upanishad. That the Br'ihad-Âran'yaka is attached to the Brâhman'a of the White Yajurveda, has been stated already.

The largest number of Upanishads, however, has grown up in connection with the Atharvaveda, which seems to have favoured more than the sacrificial Vedas the tendency for mystical reasoning. Among them we name especially the Mun'd'aka-, Pras'na-, Brâhma-, and Mân'd'ûkya-Upanishad, as treating of the nature of the divine and human soul. The Jâbalâ-, Sannyâsa-, As'rama-, and Hansa-Upanishad are some of those which describe the means by which deep meditation or the abstract union with the Supreme Soul can be obtained. A third class, as mentioned above, has a sectarian character, by identifying the Supreme Soul with Vishn'u or S'iva in their various forms; among those referring to Vishn'u we notice the Nârâyan'a-, and the Nr'isinha-tapanîya-Upanishad; among those connected with the worship of S'iva we find the S'atarudriya-, Kaivalya-, Skanda-Upanishad, and one called Atharvas'iras. (For a fuller account of this class of works, see Professor Weber's 'Akademische Vorlesungen über Indische Literaturgeschichte,' and his 'Indische Studien.')

While the Upanishads are the intermediate link between the Vedas and the later systems of Hindu philosophy, the *Vedângas* show us how scientific research grew up in India from the soil of the sacred texts. If we consider the bulk of literature which is comprised by the Sanhitâs and Brâhman'as, and the anxious desire which every Brahmanic believer must have felt to preserve it in its integrity, it is easily understood that in the course of time various means were devised for securing the correctness of the sacred texts, for guarding their sense against erroneous interpretations, and for maintaining in its purity a proper practice of the rites which were taught in the Brâhman'a. This is the object of the Vedânga works. The Brâhman'a of the Sâmaveda speak of six Vedânga or "limbs of the Veda," in other words, of six works or classes of works which were instrumental in maintaining the integrity of the Veda. But it is not certain whether this Brâhman'a means the same six Vedângas which have come down to us; Yâska, again, alludes to Vedângas, but does not state that they were six. We must distinguish therefore between categories of works which were called Vedângas, and between certain works which are the surviving representatives of these categories, but need not have been the first Vedânga works.

The doctrines comprised under this name are the following:— *S'ikshâ*, *Chhandas*, *Vyâkaran'a*, *Nirukta*, *Jyotisha*, and *Kalpa*.

S'ikshâ is the science of a proper pronunciation. One little treatise only is considered as representing this Vedânga,—the S'ikshâ ascribed to the authorship of the great grammarian Pân'ini. It consists in one recension of thirty-five, in another of fifty-nine verses, and treats of the nature of the letters, of the accents, and the proper mode of sounding them. A chapter of the Taittirîya-Âran'yaka treats likewise of S'ikshâ; but though it is possible that Pân'ini's S'ikshâ may not be the original Vedânga of this class, it is more than doubtful that this chapter of the Âran'yaka was ever considered as such.

Chhandas means "metre;" and the Vedânga which is quoted by this name is referred to the authorship of Pingalanâga. But as the work of the latter treats of Prakrit as well as of Sanskrit metres, it becomes doubtful again whether we possess in it an original Vedânga work.

Vyâkaran'a signifies "grammar," but literally means "undoing," that is, analysis; for to the Hindu scholar grammar is linguistic analysis; his grammar *un-does* words and *un-does* sentences; it examines the component parts of a word, and therefore teaches the properties of a base and affix, and all the linguistic phenomena connected with both; it examines the relation, in sentences, of one word to another, and likewise unfolds all the linguistic phenomena which are inseparable from the meeting of words. The most renowned representative of this science is *Pân'ini*, who wrote a work in eight chapters, comprising thirty-two sections and three thousand nine hundred and ninety-six rules, three or four of which, however, probably did not belong to him. And so great was the renown of this wonderful labour, which may be placed at the side of the best grammatical works of any nation and any age, that Pân'ini was looked upon as a R'ishi who had received it, by inspiration, from the god S'iva himself. Pân'ini, it is true, quotes in his work various grammarians who preceded him, but Vyâkaran'a is typified by the grammar of Pân'ini, which has remained, up to this day, the standard for Sanskrit speech. We may add, that his work was criticised and amplified by Kâtyâyana, who in his turn was criticised by Patanjali, a grammarian who lived in the middle of the second century before Christ; and that these three grammarians are considered to be the greatest authorities in the science they taught. But Pân'ini only can be held to be the representative of the Vedânga we are speaking of. Nor should the Vyâkaran'a be confounded with a class of works which apparently stands in a closer relation than itself to the Veda-Sanhitâs—with the Prâtis'âkhya works; for though the latter are concerned in Vaidik language alone, whereas Pân'ini's work is even more engaged in teaching the classical than the Vaidik dialect, their aim and their contents materially differ from those of the Vyâkaran'a. Their object is merely the ready-made word, or base, in the condition in which it is fit to enter into a sentence or into composition with another base. They are nowise concerned in analysing or explaining the nature of a word or base; they take them such as they are, and teach the changes which they undergo when they become part of a spoken hymn. Whether there existed at one period other Prâtis'âkhyas than those which have survived, it is not easy to say in the present condition of Sanskrit philology; but it has been proved that the present Prâtis'âkhyas are even more recent than Pân'ini's work. (Goldstücker, 'Pân'ini,' p. 183, ff.)

Nirukta, or "explanation," is represented by the *Nirukta* of *Yâska*, which is the oldest attempt, known to us, of an explanation of obscure passages of the Vaidik Sanhitâs. "It is important, however," says Professor Müller ('Anc. Sansk. Lit.,' p. 154), "not to confound Yâska's Nirukta with Yâska's Commentary on the Nirukta, although it has become usual, after the fashion of modern manuscripts, to call that commentary Nirukta, and to distinguish the text of the Nirukta by the name of Nighan't'u. The original Niruktas that formed an integral part of the Vedânga literature, known to Yâska himself, can have consisted only of lists of words arranged according to their meaning, like that upon which Yâska's Commentary is based. . . . Sâyana gives the following account of this matter:—'Nirukta is a work where a number of words is given, without any intention to connect them in a sentence. . . . . The first part (of the Nirukta) is the *Naighant'uka*, the second the *Naigama*, and the third the *Daivata*. . . . . The word *Nighantu* applies to works where, for the most part, synonymous words are taught. Therefore, the first part of this work also has been called Naighant'uka, because synonymous words are taught there. In this part there are three lectures: in the first, we have words connected with things of time and space in this and the other worlds; in the second, we have words connected with men and human affairs; and in the third, words expressing qualities of the preceding objects, such as thinness, multitude, shortness, &c. *Nigama* means Veda. As Yâska has quoted many passages from the Veda, which he usually introduces by the words, "For this there is also a Nigama;" and as in the second part, consisting of the fourth Adhyâya, words are taught which usually occur in the Veda only, this part is called Naigama. Why the third part, consisting of the fifth Adhyâya, is called *Daivata*, is clear. The whole work, consisting of five Adhyâyas and three parts, is called

Nirukta, because the meaning of words is given there irrespective of anything else. A commentary on this has been composed by Yâska, in twenty Adhyâyas. This also is called Nirukta, because the real meaning conveyed by each word is fully given therein.' "

The fifth Vedânga is called *Jyotisha*, or "astronomy." Its object was to teach how to fix the proper time for the performance of sacrificial acts. It is a Vaidik calendar. There is but one manuscript work, in the library of the India Office, which would seem to belong to this category, but it is difficult to say whether it may aspire to the proud name of a Vedânga work.

The sixth Vedânga, on the contrary, the *Kalpa*, is represented by a great number of works, several of which are preserved in manuscripts in our libraries. *Kalpa* means "ceremonial," and the works of this class are the code of the Brahmanic rites. It was stated before that the Brâhman'a portion of the Veda contains explanations of the purposes for which the verses of the Sanhitâs were used, in consequence that it conveys a knowledge of the Vaidik rites. This knowledge, however, which apparently sufficed for the period at which these works were composed, must have been deemed insufficient at later ages, which required a more copious detail for a proper performance of the rites. Moreover, the Brâhman'a, as a first attempt, are wanting in proper arrangement of the matter they contain, and abound in legendary narratives, which interrupt their comment on the sacrificial acts. The Kalpa-Sûtras remedy this practical defect; they contain a complete system of the Vaidik rites according to the Veda to which they belong. Of such Kalpa-Sûtras, those connected with the ceremonial of the R'igveda are, the Sûtras of S'ânkhâyana, Âs'walâyana, and S'aunaka. Kalpa-Sûtras explaining the rites of the Sâmaveda are those of Mas'aka, Lât'yâyana, Gobhila, Drâhyâyan'a, and a Sûtra called Anupadasûtra, which explains the ceremonial taught in the Panchavins'a-Brâhman'a. Kalpa-Sûtras of the Black Yajurveda are the Âpastamba, Baudhâyana, Satyâshâdha-Hiranyakes'in, Mânava, Bhâradwâja, &c.; of the White Yajurveda, that of Kâtyâyana; of the Atharvaveda, that of Kus'ika.

Two other classes of Sûtras gradually completed the code of these Kalpa works, which, in being founded on S'ruti or the Veda, bear also the name of *S'rauta-Sûtra*, namely, the *Gr'ihya-* and the *Sâmayâchârika-Sûtras*. The Gr'ihya-Sûtra describe the domestic ceremonies, as distinct from the great sacrificial acts enjoined by the S'rauta or Kalpa works: " First, the marriage ceremonies; then the ceremonies which are performed at the conception of a child, at various periods before his birth, at the time of his birth, the ceremony of naming the child, of carrying him out to see the sun, of feeding him, of cutting his hair, and, lastly, of investing him as a student and sending him to a Guru, under whose care he is to study the sacred writings. . . . It is only after he has served his apprenticeship and grown up to manhood that he is allowed to marry, to light the sacrificial fire for himself, to choose his priests, and to perform year after year the solemn sacrifices prescribed by Smr'iti and S'ruti. The latter are described in the later books of the Gr'ihya-Sûtras; and the last book contains a full account of the funeral ceremonies and of the sacrifices offered to the spirits of the departed." (Müller, 'Anc. Sansk. Lit.,' p. 204.)

The Sâmayâchârika-Sûtras regulate the relations of every-day life. " It is chiefly in them that we have to look to the originals of the metrical law-books, such as Manu, Yâjnavalkya, and the rest." (Ibid., p. 200.) Both these Sûtras are comprised under the name of *Smârta-Sûtra* (from *Smr'iti*, "tradition"), as they are based on it. Of the Gr'ihya-Sûtras of the R'igveda, we possess those of S'ânkhâyana and Âs'walâyana; a Gr'ihya-Sûtra of the Sâmaveda is that of Gobhila; the Yajurveda in both its recensions seems to have had many Sûtras of this kind. Of the Black Yajurveda, we name especially the Baudhâyana; and of the White Yajurveda, the Pâraskara Gr'ihya-Sûtra.

We conclude these outlines of the principal works of the Vaidik literature with mentioning another class of compositions which arose from the desire of securing the integrity of the Vaidik texts, as well as the traditional and exegetic material connected with them,—the *Anukraman'î*, or Indices to various portions of this literature. The completest of this kind is that by Kâtyâyana, to the R'igveda-Sanhitâ. It gives the first words of each hymn, the number of verses, the name and family of the poets, the names of the deities, and the metres of every verse. Its name is *Sarvânukraman'î*,—that is, " the index of all things;" and it seems to have improved on four similar writings which preceded it and are ascribed to S'aunaka. For the Yajurveda there are mentioned three Anukraman'î, for the Samâveda two, and there is one for the Atharvaveda. (Müller, 'Anc. Sansk. Lit.,' p. 215, ff.)

It would be but natural to ask, what date could be assigned to all or any of the various works which have been named in the course of this brief sketch of Vaidik literature; but Sanskrit philology is as yet not able to answer this question satisfactorily. It may offer conjectural dates according to the impressions of the individual mind, but it is bound to avow that past research has not provided it with facts which would impart to its chronological surmises any degree of plausibility.

VEDANTA. [Sanskrit Language and Literature, col. 269.]

VEDUR. [Veadar.]

VEERING, or WEARING (from the French, *virer*), is that movement of a ship in which, supposing her to have been previously sailing with the wind on either bow, she is brought, by her head being turned to leeward, into such position that the wind is on the *other* bow, and she is brought round on an opposite tack. A reference to our word Tacking will show that during that operation the ship's head is brought to the wind, while in the act of veering it is quite the reverse.

If in tacking the ship loses so much of her forward motion as to be incapable of yielding effectually to the action of the water on the rudder, and thus of turning her opposite bow towards the point from whence the wind is blowing, the ship is said to miss stays; she then drifts to leeward, till, by the action of the water on the lee side of the rudder the head is again turned from the wind, when she is brought to her previous position. In this case, should it be necessary to persevere in endeavouring to change the course, and should the ship be not too near a point of danger, the proposed end may be gained by veering, and the evolution is thus effected:—When, in drifting to leeward, the ship begins to fall off, or to turn her head from the wind, the helm is placed hard a-weather, and the after-sails are hauled up so that the wind may act upon the head-sails only, and that the ship may be brought before the wind; when, the velocity of rotation continuing, the ship's head begins to turn towards the wind, which will then be on the opposite bow. The helm being now turned to leeward, and the after-sails set, the ship comes rapidly into the required position.

This evolution is frequently the only one which can be performed in stormy weather when little sail can be carried, and also when sailing with a light breeze; since, in either of these cases, the ship may not have sufficient velocity to allow of being put about by tacking: the disadvantage of veering is that, during the evolution, the ship is sometimes carried far to leeward, and the loss of space can only be diminished by executing the movement with as much rapidity as possible.

When a heavy sea is running, veering is a perilous operation, as may be inferred from the following diagrams. During a hard gale good experience in seamanship is required in order to prevent the decks being swept by the waves. There are two periods, while a ship is veering, at which the danger is most threatening: namely, soon after a ship's head has payed broad off when she is liable to be caught in the trough of the sea, as in *fig.* 1; and, next, when she has come with head right off the wind, and is scudding, as in *fig.* 2. In either case the breaking of the sea upon deck might destroy everything thereon, if it did not lead to the foundering of the vessel. The latter case is that of a ship receiving a sea over the stern, when she is said to have been "pooped." In small fore and aft vessels, and especially in open boats, veering is attended with some risk even in moderate weather, and should be always done with caution; the sudden "swag" of the mainsail and boom from one side to the other as the wind catches the vessel upon the other quarter, may snap the boom with the suddenness of the jerk, or capsize the vessel altogether. To obviate this it is proper to round in the main sheet as it comes aft, and then check and ease it.

Fig 1.

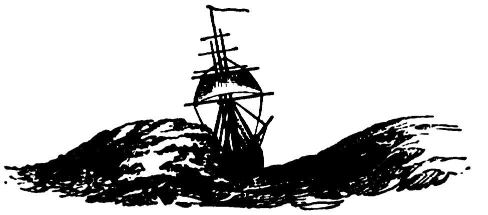
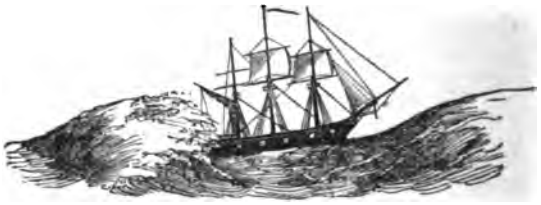


Fig. 2.



Box-hauling is an evolution similar to that of veering, and is put in practice when a rock or some other danger is suddenly seen a-head. If it be supposed that the ship is already close hauled, the after-sails are to be taken up, the helm turned a-lee, and the head-sails laid back; by these means the ship's head begins to turn from the wind, and her forward motion is arrested. As the ship's head continues to turn, the wind begins to act on the after-surfaces of the head-sails, giving a small motion forward; and then the helm is shifted so as to co-operate with the wind in causing the ship's head to fall farther off. The rest of the evolution is similar to that which is performed in the act of veering.

VEGETABLE ALKALOIDS. [Base; Organic Bases.]

VEGETABLE CASEIN. [Legumin.]

VEGETABLE GREEN. [Colouring Matters.]

VEGETABLE IVORY. [Ivory.]

VEGETABLE LEATHER. [Leather Manufacture.]

VEGETABLE PARCHMENT. [Parchment, Vegetable.]

VEGETABLE ROUGE. [Carthamin.]

VEGETABLE SCARLET. [Carmine.]

VEGETABLE SILK. [Silk Manufacture.]

VEGETABLE WAX. [Wax.]

VEGETO-SULPHURIC ACID. [Sugar.]

VEINS, DISEASES OF. The physiology of the veins may be found in the article Circulation, in Nat. Hist. Div.: in the present article their principal diseases will be described. Of these the most frequent is that in which they become what is called *Varicose*, that is, dilated, and unnaturally tortuous, a disease which occurs especially in the subcutaneous veins of the lower extremity. It is the result of the coats of the veins losing their elasticity, and thereby their power of resisting the pressure of the column of blood above them. The loss of elasticity is commonly due to disease of their coats, and is frequently accompanied by an increase of their thickness, and by destruction or impairment of their valves. The dilated veins appear like large tortuous blue canals beneath the skin, or in extreme cases, where many are coiled together, they form projecting tumours. They produce inconvenience, both by the pain which results from their distension, and occasionally by the skin over them ulcerating, and allowing them to burst and bleed profusely; but their more common effect is, that in parts of the skin below them, either spontaneously or after slight injuries, ulcers form, which, in consequence of the circulation being impeded through the dilated veins, are very tedious in healing.

For this varicose state of the large veins numerous remedies have been proposed; but the best are only palliative. A temporary remedy is afforded by the recumbent posture, in which the walls of the veins are relieved from the weight of the column of blood: constant advantage is afforded by the wearing of a well-applied bandage, or of an elastic stocking, by which a sufficient pressure is applied to prevent the further distension of the veins. The obliteration of the venous trunks may be effected by cutting or tying them in various ways, or by applying some caustic, so as to make the tissues over them slough; but these proceedings are not without danger, and at present it is very doubtful whether they are often productive of permanent advantage. Patients had better, in general, be content with the palliative remedy of the bandage or elastic stocking.

A form of varicose disease of the veins, which often accompanies that of the venous trunks, but sometimes exists alone, and with which ulcers of peculiar obstinacy occur, affects the small vessels about the ankle and lower part of the leg. The skin in this disease is almost uniformly red, through the number of small veins that are distended; the neighbourhood of the ulcer, when one exists, is livid, tense, and shining; and the ulcer itself is indolent, and very painful, and discharges a thin sanies. This state can be treated only by the same remedies as the preceding: but, though commonly overlooked, it is by far the more mischievous disease of the two.

Varicose affection of the veins of the spermatic cord constitutes the disease named *Varicocele;* and that of the veins of the rectum, or skin around it, forms hemorrhoids, or piles. In these, and in all the other cases, the blood is apt to stagnate in the dilated veins, and to coagulate within them. The clots thus formed may assume a definite form, becoming elliptical, or more often elliptical with pointed extremities, and the fibrine in them arranges itself in concentric layers: after this they harden, and one of their extremities becoming connected with the walls of the vessel, small blood-vessels may form in them, and communicate with those of the surrounding parts. Lastly, the colouring-matter of the blood is removed, and earthy-matter is deposited in the clots, arranged in concentric layers, and giving them considerable hardness: thus *phlebo-lithes*, or vein-stones are formed. They are usually spherical, measuring from one to four lines in diameter, lying loose within the veins, and producing no apparent inconvenience, except by obstructing the passage of blood. They are especially common in the dilated veins in the pelvis of old persons, and in the veins of legs which have been long varicose: they neither need nor admit of surgical treatment.

That which is particularly termed a *Varix* is either a mass of dilated and tortuous veins, or a single saccular and circumscribed dilatation of a vein, analogous to the circumscribed aneurism of an artery. This circumscribed dilatation is a very rare disease, but in its consequences does not differ from ordinary dilatation. An aneurismal varix is produced when, a communication being made, either by a wound or by ulceration, between an artery and a vein, the latter is dilated by the force of the arterial blood into a circumscribed sac. [Aneurism.]

The most serious disease to which the veins are subject is acute inflammation, or *phlebitis*. It sometimes occurs after the slight wound made in ordinary bleeding; it is more common after operations upon varicose veins; and yet more frequently occurs after amputations of the limbs. Slight cases of phlebitis not unfrequently come on, as if spontaneously, or after exposure to cold, in varicose veins. The dilated veins become hard, like knotted cords beneath the skin, and very painful; the skin around them inflames, and the parts below become œdematous; and sometimes a slight erysipelas spreads over the limb. Such affections are usually of little moment; leeches, rest, and external cold are sufficient to subdue the inflammation, and it often has the favourable result of obliterating the veins, and thus curing the disease by which they were previously affected.

The more severe phlebitis is a most dangerous disease. Lymph is effused into the cavity of the vein, and into the tissue of its walls, rendering them thick and hard; the vein and the tissues immediately around it become exquisitely tender, and the parts whose blood should be returned through the diseased vein are usually œdematous. In a further stage pus is effused into the cavity of the vein, and, mixing with the blood, it may pass into the general current of the circulation, though more commonly the vein is obliterated above the chiefly inflamed part by lymph deposited on its walls, and thus the passage of pus into the circulation is prevented. With the local inflammation of phlebitis a state of low typhoid fever, with muttering delirium and great exhaustion, is usually combined; and under these the patient dies.

In connection with suppurative phlebitis a condition often occurs to which the name of *purulent diathesis* has been given. Its chief characteristic is, that collections of matter form coincidently in many different parts of the body, most frequently in the joints, lungs, and liver, accompanied by a kind of fever similar to that which attends phlebitis. It has been thought that this state depends on pus formed in an inflamed vein being carried into the circulation, and deposited again in some remote part; or that there is a kind of metastasis of suppuration from the vein to the parts secondarily affected. But cases occasionally happen in which all the signs of the purulent diathesis are well marked, although no vein is diseased; so that there is no necessary connection between the disease and phlebitis, although in the tendency to suppuration the veins generally take a prominent place. The most probable explanation of the disease is, that some morbid matter, such as is formed in the decomposition of the discharge from sores or wounds, is introduced into the blood, whose chemical composition it impairs, engendering a state in which pus is apt to be formed, and in which, as in typhoid fever, every function is seriously disordered.

The treatment of these cases of acute phlebitis and purulent diathesis cannot be laid down in general terms. Very commonly the former requires the coincident employment of large local bleedings, and of medicines and regimen calculated to maintain the patient's strength. The due observance of the indications for one or both of these proceedings affords the only prospect of success; but most frequently the best directed means are ineffectual.

One of the most fatal forms of phlebitis is that which affects the veins of the uterus and the neighbouring parts after labour, and which chiefly constitutes one of the diseases included under the name of puerperal fever. *Phlegmasia dolens*, or *phlegmasia alba*, is due to phlebitis of a less severe kind affecting the iliac or femoral vein, or both, and many others adjacent to them. By obliterating the venous trunks, and preventing the circulation through them, the disease gives rise to the firm œdema, accompanied by the tightness and glossy paleness of the skin of the leg and thigh, which peculiarly indicate it. It occurs sometimes, but rarely, after exposure to cold: its usual origin is in a comparatively slight inflammation of the veins of the pelvis of women during pregnancy, or after delivery, which extends from them to the veins of the lower extremity. It is attended by the same tenderness and hardness of the diseased veins as exist in other cases of phlebitis; and in its treatment, as in theirs, the general state of the patient's health, and the degree and extent of the local affection, considered together, must determine the measures to be adopted.

VELLUM. [Parchment.]

VELOCITIES, VIRTUAL. [Virtual Velocities.]

VELOCITY. This word, rendered into English, is simply swiftness or quickness, and would be soon disposed of, if it were not that various circumstances connected with its measure and calculation render its consideration one of the most useful exercises which the student can have, not only in mechanics, but also in pure mathematics. And since the views which must be developed in treating properly of this word are almost identical with those which arise in explaining the meanings of other words nearly as important, we have made references from all quarters to this article, which, though they will increase its length, will upon the whole save room.

The difficulty in the way of a beginner, which he meets with in acquiring a clear notion of the measure of velocity, is the tendency to confound the velocity and its measure; a tendency which is increased by any elementary work which hastens too rapidly to the mathematical treatment of the word. The consequence of this confusion is (since the measure of velocity must be a length described, or rather a length capable of being described) a want of power to distinguish between the space which a body *does* describe in a given time, and that which, judging from its velocity, it seems to be going to describe at the beginning of that time. Hence arise many notions mathematically false: these might perhaps be prevented by attributing volition to the moving particle, and distinguishing between its apparent intention at the beginning of the given time and that which it actually accomplishes in the given time. Such an illustration would probably receive no approbation; but the errors to which it would lead would not be of the least consequence in mathematics.

A point is in motion, and during a certain second it moves over ten feet: if the same thing should happen in preceding and succeeding seconds, there is a presumption that the body is moving uniformly at the rate of ten feet a second; that is to say, there is a presumption that, in any portion of time whatsoever, during its motion, there is a length described which bears to ten feet the same proportion as that portion of time bears to one second. But this is a presumption only. It does not follow, because ten feet are described in one second, that five feet are described in each half of a second, and one foot in each tenth of a second. If the second could be divided into a million of parts, and it could be shown that the millionth part of ten feet is described in each and all of these parts, it would be no doubt a very strong presumption that the motion is really uniform, but still not amounting to certainty; for it is possible that in each of those parts of time there may be a variation of speed: for instance, the moving point may do all its work in the first half of the small interval, and rest during the remainder. Something of this kind takes place in the motion of the minute-hand of a clock, which is propelled once in each second during a portion of the second, and rests during the remainder. But so rapidly do the small propulsions follow one another, and so small are their individual effects, that, even when the hand has been watched until its motion is certain, there is no irregularity discoverable by ordinary eyes. And, speaking with reference to common purposes, there is no occasion to deny uniformity of motion so long as the lengths described in those times which are convenient to be mentioned are equal or nearly equal. It would be useless, in speaking of the pace with which a man walks four miles an hour, to remind the hearer that no person walks uniformly, and that in every step the centre of gravity of the body moves up and down, advancing most rapidly when it is at the highest, and most slowly when it is lowest. But for mathematical purposes a correct measure of speed must be obtained, and the preceding account would at first seem to lead to the inference that it is impossible to have such a measure. Nor indeed has velocity yet received its definition in this article, at least not its measure: we have spoken of velocity and of its changing, but without alluding to any mode of estimating the quantity of change. But there is that about the word which needs no definition: when we say that the railroad carriage moves "faster" than the old stage-coach, or that two bodies which set out together and keep together are always moving "at the same rate," there is no need of explanation of the words which are in marks of quotation. And we must now refer to the considerations in UNIFORM, as a constituent part of this article, showing that we may have a perfect idea, both of velocity that it is a magnitude, and that there is such a thing as uniform velocity, previous to any definite ideas of the most proper mode of measuring even that uniform velocity, to go no farther.

If a body move uniformly, it is customary at once to lay down as the measure of the velocity the space described in a given time, usually the unit of time, a second, a minute, an hour, as the case may be. So far as the great object of calculation is concerned, this definition is perfect: by instituting measures of velocity, we can but want to answer one or other of these questions: Where will the moving point be at the end of a given time? or, In what time will the moving point pass over a given length? The body moves at the rate of v feet per second, it moves over vt feet in t seconds, and moves over the length s feet in $s \div v$ seconds. Let us now take a point moving with a variable motion, that is, not describing equal lengths in equal times, say a particle descending by its own weight in a vacuum. In the first second it falls 16 feet; but in the first half of this second it falls only 4 feet, and the remaining 12 feet in the second half-second. The space described in one second is therefore no measure of the rate of motion during that second, and it is now to be asked, What is the way of obtaining a measure of the speed after any interval has elapsed? What is velocity itself, when it cannot for want of uniformity be ascertained by the space described in any given time? If the action of gravity were removed at the end of that time, so that the point would go on uniformly with its last acquired velocity, how much would it then describe in one second? All these questions are the same, and the answer cannot be given without the introduction of the notion of a limit, whether with or without the forms of the differential calculus. At the end of the time t seconds, let the moving point be at A, distant by s feet from the fixed point O. During the ensuing fraction h of a second, let it describe the further space AB $(=k)$. The length k is then moved over in the time h, and, if the velocity were uniform, that velocity would be $k \div h$ feet in one second; for as h is to 1 (second), so (on the supposition of uniform velocity) is k to the space which would be described in one second. If AB were very small, we might reason (with tolerable exactness) as follows: In a very small time the change of speed will be slight, and the motion of the point nearly uniform, though not absolutely so; whence we may say, without material error, that AB is described as with a uniform velocity at the rate of $k \div h$ feet per second. The process which the mathematician adds is the following:—The error of the preceding process, small when h is small, becomes smaller when h is still smaller, and may be diminished to any extent: that is, little as may be the departure from uniform motion in moving through a small length, it is less in moving through a smaller. If, then, instead of making h simply small, and then finding $k \div h$, we diminish h without limit, and find the limit towards which $k \div h$ approaches, we find that uniform velocity which may be said to represent the speed of the point in passing through A, so far as any uniform velocity can be said to do so. Using such language as supposes the point to have volition, we have, in the limit of $k \div h$, the length per second with which the point shows an intention of proceeding at the instant when it passes through A, though it does not preserve that intention wholly unaltered for any portion of time, however small.

Suppose for example that the point moves in such a way as to describe $t+t^2$ feet in t seconds, for all values of t, whole or fractional. We have then $s=t+t^2$, $s+k=(t+h)+(t+h)^2$, whence we obtain

$$k=h+2th+h^2 \qquad \frac{k}{h}=1+2t+h.$$

At the end of three seconds, what is the velocity? Judging from the length described during the succeeding fraction h (and making $t=3$), we should say that, $k \div h$ being $7+h$, the limit of this, or 7, obtained by diminishing h without limit, is the velocity required; that is, the point is then moving 7 feet per second. If we suppose 7 feet per second, the length described in the fraction h of a second is the fraction $7h$ of a foot; take any other uniform velocity p feet per second, and ph is the length described in the same time. Now what is really described is $7h+h^2$; so that the errors are h^2 and $(7-p)h+h^2$, which are in the ratio of h to $7-p+h$. Now if p differ (as we have supposed) from 7, the first error diminishes without limit as compared with the second, when h diminishes without limit: so that, *of all uniform velocities*, 7 feet per second is the one which best represents the motion of the point in any small time following the end of the third second; and the better the smaller the time.

It appears then that we do not, properly speaking, undertake to say at what rate the point is moving at the end of three seconds, but what fictitious *uniform* rate best represents, at the instant, the *variable* rate at which it is moving. This will, for a moment, seem rather unsatisfactory to the student who imagines that he has got an absolute idea of velocity, and here he should compare his notion on this subject with that of the direction of a point moving in a curve. [DIRECTION; TANGENT.] What do we mean by saying that a point which moves in a curve has, at every instant, the direction of motion which is represented by the tangent of that curve? Answer, in nearly the same words as before, We do not, properly speaking, undertake to say in what direction the point is moving at any period of its motion, but what fictitious *line of uniform direction* (straight line) best represents, at that instant, the *line of variable direction* (curve) on which it is moving. The study of these two things together, velocity and direction, is useful, as each throws illustration upon the difficulties of the other. In both cases the laws of matter agree in preferring that which is indicated as most simple by the laws of mind; for if a point moving along a curve be suddenly relieved of the forces which keep it in a perpetual change of speed and direction, it will proceed with that very velocity which we have said it shows its intention to proceed with, uniformly; and will quit the curve for that straight line which we might equally well have said it showed a disposition to prefer to any other while moving on the curve, namely, the tangent of the curve.

If it should be said that we are reduced, in treating of variable velocities, to a necessity which does not occur in describing those which are uniform, namely, the use of limits, we altogether deny the fact; that is, we say that we are as much compelled to the use of limits in defining a uniform velocity as a variable one. For what does uniform velocity mean? A point has uniform velocity when equal spaces, any equal spaces whatsoever, are described in equal times; or when, k being described in the time h, $k \div h$ is always the same. That is, $k \div h$ must retain its value, however small h may be; or the limit of $k \div h$ must also have that value. And we have seen that it would be impossible to declare, experimentally, the existence of uniform velocity, even if our senses had no imperfections, upon the experience of comparisons of any finite equal spaces, however small; nothing but assurance of *the limit of* $k \div h$ being the same thing wherever the point A might be placed, would give mathematical evidence of the velocity being uniform.

In all cases, then, by the velocity of a point in motion, at any particular period of its motion, is to be understood the limit of the ratio which the increment of the length described bears to the increment of the time expended in the description of that increment of length. That is, if the length be measured in feet, and the time in seconds, and if k be the fraction of a foot described in the fraction of a second h, the limit towards which the fraction k divided by the fraction h continually tends while h is diminished without limit, is the number of feet per second which, we may say, expresses the rate of motion at the period in question. The student of the differential calculus will now have no difficulty in altering the preceding into the following form: if the length s be described in the time t, the velocity (v) at the end of the time t is thus expressed:

$$v=\frac{ds}{dt}.$$

If y be any function of x, and if x represent the number of units of length described by a moving point in the time t, and y the same for another moving point, and if $y=\phi x$, we have by the rules of the differential calculus:

$$\frac{dy}{dt} = \frac{dy}{dx}\frac{dx}{dt}.$$

Here $dy : dt$ and $dx : dt$, represent $\dot{y}$ and $\dot{x}$, Newton's Fluxions of y and x; and $dy : dx$ is obviously the same thing as $\dot{y} : \dot{x}$. The term fluxion merely means velocity, and, after all, there can be formed no clearer notion of a differential coefficient than one which is formed from a consideration closely resembling the fluxional one. If y be a function of x, $dy : dx$ is the rate at which y is increasing, as compared with that at which x increases. Thus if $y=x^4$, $dy : dx=4x^3$, which when $x=10$ is 4000. What does this mean? We say that nothing can answer more clearly than the following: If a number be imagined to be gradually increased [Variable], by the time it becomes 10 its fourth power will be, at that instant, increasing 4000 times as fast as itself.

Acceleration is the increase of velocity; and in the article cited uniform acceleration has been considered, and its laws deduced, if not with the forms, yet on the principles, of the differential calculus. Precisely the same difficulties come before us in the development of the measure of acceleration as in that of velocity, and they are to be met in the same manner. In fact, by the acceleration is meant the rate of increase of the velocity, the velocity of the velocity. Suppose the velocity, first, to increase uniformly: that is to say, let b feet be added to it in every second, and in that proportion for all times elapsed; if then a be the initial velocity, that at the end of the time t is $a+bt$, and we have

$$\frac{ds}{dt} = a + bt \qquad s = at + \tfrac{1}{2} bt^2$$

if s be measured from the point of starting. Here at is the length due to the initial velocity a, and $\frac{1}{2}bt^2$ the effect of the continual acceleration. Now suppose, returning to the diagram, that the velocity at B is greater by l than that at A, and the fraction h of a second having elapsed between the two positions: that is, suppose that at A the point begins to move as if it meant (continuing our illustration) to describe v feet in the next second; but that by the time of coming to B it begins (from B), as if it would describe $v+l$ feet in the next second. If this increase of velocity were uniformly given, that is, if in the time $\frac{1}{2}h$ its velocity had become $v+\frac{1}{2}l$, in $\frac{1}{3}h$, $v+\frac{1}{3}l$, and so on for every fraction of h, we might then infer that the acceleration at A, that is, the rate at which velocity is then increasing, measured by the quantity which would be gained in a second at the same rate, is $l \div h$: for as h is to one second, so is l gained in the time h to what would be gained in a second at that rate. But if this supposition be not true, that is, if the speed receive *unequal* additions in equal times, we must then begin to reason as before, and to find what (pursuing the same illustration) we may call the intention of the velocity. If l be added to the velocity in the small time h, it will be added nearly uniformly; if h be still smaller, still more nearly, and so on: in such manner that while, practically speaking, $l \div h$ is a sufficiently good representative of the current rate of acceleration, when h is small, the (uniform) rate of acceleration which best represents the state of things at A is the limit which is deduced by making h diminish without limit. And here again, copying our own preceding words, we do not undertake to say at what rate the velocity is increasing when the moving point is at A, but what fictitious *uniform* rate of increase best represents, at the instant, the *variable* rate of increase which would be detected if the changes of velocity between A and B could be noted. And hence, if w be called the acceleration, the student of the differential calculus will easily deduce,

$$w = \frac{dv}{dt} = \frac{d^2s}{dt^2} \text{ since } v = \frac{ds}{dt}$$

and also $vdv = wds$.

Thus if the motion of the point be such that in t seconds there are described t^3+t^4 feet, we have as follows:—

$$s = t^3 + t^4,\ v = 3t^2 + 4t^3,\ w = 6t + 12t^2$$

At the end of two seconds, then, the state of things is this:—the point has advanced 8 + 16 or 24 feet, and if allowed to move on without further change of velocity, would describe 12 + 32 or 44 feet in the next second, and has the velocity 44 (feet) in one second; while at the same time there is an acceleration taking place which would, if allowed to remain uniform for one second, add 12 + 48 or 60 to the velocity, making it 44 + 60 or 104 at the end of the third second. But this rate of acceleration is itself increasing, since at the end of the third second the velocity is 27 + 324 or 351.

So far the subject, and all notions connected with it, fall within the province of pure mathematics: if there were no such thing as either matter or force, but only motion and a mind to conceive it, all that has been said might be intelligible. It is very much to be regretted that the connection between the mathematical doctrine of motion and the laws of matter is unduly made, and at too early a stage, by the application of the term *accelerating force*, instead of simple *acceleration*, to the result $dv : dt$. Acceleration would be what we have described it to be, if matter were not inert, if it moved by its own volition, or on any supposition whatever, provided only that it moved. Why then should a theory be made to supply the name of a result antecedent to that theory, and which would be perfectly true even if that theory were false? The consequence of this is, that when the laws of matter come to be applied to the mathematical expressions of motion, things are taken for granted which ought to be learnt.

The connection between these two subjects is made in the manner described in the article Force, according to which it appears that if the weight of a particle be W, and if (this weight being taken away, as by laying the particle on a table without friction) a pressure be constantly exerted upon it such as would be produced by a weight P, in any direction in which it can move freely, the amount added to the velocity will be uniform, at the rate of 32·19 P ÷ W feet in every second. Hence the following equation:—

$$\frac{32 \cdot 19\ \mathrm{P}}{\mathrm{W}} = \frac{dv}{dt},\ \text{or}\ \mathrm{P} = \frac{\mathrm{W}}{32 \cdot 19}\frac{dv}{dt}.$$

For example, what pressure must act uniformly for one second on a particle of 7 ounces weight, to add 13 feet per second to its velocity, or that the rate of motion at the end of that second may be 13 feet per second greater than at the commencement? Here $dv : dt=13$, $\mathrm{W}=7$, and the answer is

$$\mathrm{P} = \frac{7 \times 13}{32 \cdot 19} = 2 \cdot 83 \text{ ounces.}$$

The numerical divisor 32·19, the uniform acceleration of bodies falling free in vacuo at the earth's surface, is usually denoted by g, and the factor $\mathrm{W} \div g$ usually stands for the Mass of the body, or the measure of its quantity of matter. Hence the following equation:—

$$\mathrm{P} = \mathrm{M}\frac{dv}{dt};$$

and this remains true, whatever unit of mass be employed, provided only that the pressure which is called unity shall be that which, exerted for one second upon the unit of mass, shall add a unit to the velocity. [Variation.] And now comes another consequence of the application of the term force to the simple consequence of force, acceleration. The word is wanted again to signify this pressure which produces acceleration, and for distinction the pressure is called *moving force*. [Momentum; Moving Force.] So, then, the name of the pressure which acts and produces continual accessions to the speed is moving force, while the name of the rate of acceleration is accelerating force. To mend this confused use of terms, some writers endeavour to create a notion of moving force independent of the pressure; but as they always end in saying that the moving force varies as the pressure and never tell us more of its definition than that it is the product of the mass and acceleration, they might save themselves trouble, and their readers also, if they would simply establish the above equation, where P means the pressure which produces acceleration, and that pressure is the unit of its kind when it is of that magnitude which creates in the unit of mass a unit of velocity per second.

As we are now differing from men of deservedly good authority, both at home and abroad, and intending to make our assertion in a more positive manner than is usual with us, we may be excused for dwelling a little more upon the subject. If we consider the natural meaning of moving force and accelerating force, it is obviously as follows:—Moving force is force which makes motion; accelerating force is force which makes acceleration, or increased motion. Were the distinction ever so necessary, these words would be very bad ones, and would always obstruct the learner. Nor does this origin of the word moving force—namely, that which produces Momentum—give any help; for the synonyme for momentum—namely, *quantity of* motion, meaning really quantity of matter moved multiplied by the velocity—is a perversion of words of the same kind. To *momentum* we have no objection; it is a Latin word to which an English ear may easily be familiarised in any sense. If geometers had chosen to call an equilateral triangle a *momentum*, the etymological student might have been startled, but the shock would soon have been got over; but if they had called the same figure a *quantity of motion*, every beginner would have been puzzled, and the impression would have been lasting. But returning to the two species of forces, so called, we find a double inconsistency: the idea of motion is introduced into the word which only means pressure (for *moving force* is but pressure), while the idea of pressure is introduced into a word which has only reference to motion (for *accelerating force* is but acceleration). There are two distinct and leading ideas in mechanics, pressure and motion: on keeping them perfectly distinct till the time comes for joining them experimentally it must depend whether a student sees mechanics to be a science or not. If any one should say that pressure producing motion ought to be distinguished from pressure which is in a state of equilibrium with other pressures, we could not of course raise any objection: let, then, *moving force* and *resting force* be used in these two senses, with a clearly expressed distinction. Here force would be synonymous with Pressure, in the derived or secondary sense of the article cited. But let acceleration be then acceleration, not accelerating *force*.

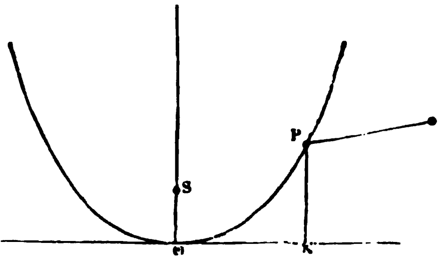
The Composition of velocities and accelerations is so easily proved that we do not think it necessary to lengthen this article by dwelling upon it. Two of a sort, whether velocities or accelerations, acting upon one particle, at any one instant, are equivalent to a third represented in magnitude and direction by the diagonal of a parallelogram, the two sides of which represent in magnitude and direction the two components. And by the law of motion which is commonly called the second [MOTION, LAWS OF], the several accelerations which act on any particle *in any given directions* may have their effects computed separately without any error being introduced. If, then, supposing a particle to move in a plane, the pressures P and Q be applied to it in the directions of the rectangular co-ordinates x and y, the mass of the particle being M, we have

$$\mathrm{M}\frac{d^2x}{dt^2} = \mathrm{P}, \quad \mathrm{M}\frac{d^2y}{dt^2} = \mathrm{Q}$$

equations which are only true on the supposition that there is this connection between the unit of mass and that of pressure, namely, that the latter acting on the former during one unit of time shall add to the line which represents its velocity one unit of length. These equations are enough to determine the equation of the curve in which the particle must move, P and Q being given functions of both x and y; and the time of motion through any arc of the curve s is then found from the following equation:—

$$\left(\frac{ds}{dt}\right)^2 = 2\int(\mathrm{P}dx + \mathrm{Q}dy) \text{ or } dt = \frac{ds}{\sqrt{\int(2\mathrm{P}dx + 2\mathrm{Q}dy)}}.$$

It is not here our business to proceed further with the consequences of the definitions of velocity and acceleration; but we must explain a point which will arise in our subsequent article on VIRTUAL VELOCITIES. When we have the means of actually ascertaining the motion of a particle of given mass,—that is to say, of finding at every instant its actual place, its velocities in the directions of its co-ordinates, and its accelerations in those directions,—we are prepared to assign the pressures which must act upon it in those directions, at the instant we are speaking of, either in mathematical units of pressure, as before described, or, if the reader please, in pounds or ounces averdupois. To show this, let us propose an instance, as follows:—A particle whose weight (if weight were allowed to act) is 10 ounces, moves uniformly along the arc of a parabola O P (whose focus is S, O S being half a foot) at the rate of 2 feet per second: What pressures in the directions of O N and N P (or of x and y) are necessary to keep up the motion; and in particular what are the pressures and the velocities at the point P at which N P = 3 feet? The equation of the curve is $2y = x^2$, whence we get



$$\frac{dy}{dt} = x\frac{dx}{dt}.$$

Or the velocity in the direction of y is to that in the direction of x always as x to 1.

But, s being the arc O P, we have

$$\frac{ds}{dt} = 2, \quad \frac{ds^2}{dt^2} = \frac{dx^2}{dt^2} + \frac{dy^2}{dt^2} = 4$$

$$\text{whence } \frac{dx^2}{dt^2} = \frac{4}{1+x^2} \quad \frac{dy^2}{dt^2} = \frac{4x^2}{1+x^2}.$$

At the point in question $y=3$, $x^2=6$, from which the velocities in the directions of x and y are found to be $\pm\sqrt{(\frac{4}{7})}$ and $\pm\sqrt{\frac{24}{7}}$, or ·756 and 1·852. We take the positive signs, since both motions obviously tend to increase* their co-ordinates. Differentiate the last equations again, and we have,—

$$2\frac{dx}{dt}\frac{d^2x}{dt^2} = -\frac{8x}{(1+x^2)^2}\frac{dx}{dt}, \quad 2\frac{dy}{dt}\frac{d^2y}{dt^2} = \frac{8x}{(1+x^2)^2}\frac{dx}{dt}$$

$$\frac{d^2x}{dt^2} = -\frac{4x}{(1+x^2)^2} \qquad \frac{d^2y}{dt^2} = \frac{4}{(1+x^2)^2},$$

or the velocity in the direction of x is always retarded, while that in the direction of y is always accelerated. And at the point in question we have $-4\sqrt{6}\div 49$ and $4\div 49$ for the accelerations, say $-$·200 and ·082; by which we mean that if the pressures then acting in the directions of x and y were allowed to continue uniform for one second, they would alter the velocities in the direction of x and y from ·756 and 1·852 to ·756 $-$ ·200 and 1·852 + ·082. The weight of the particle, if weight* were allowed to act, being 10 ounces, the pressures which would produce the preceding accelerations are, in ounces—

$$-\frac{10}{32\cdot19}\frac{4x}{(1+x^2)^2} \text{ and } \frac{10}{32\cdot19}\frac{4}{(1+x^2)^2},$$

the pressures in the direction of x being in the direction from N towards O. At the point in question these pressures are $-$·062 and ·0255 ounces.

The pressures thus derived from the motion which actually takes place, by means of the accelerations $d^2x : dt^2$ and $d^2y : dt^2$, are usually called the *effective* forces; and the name is very appropriate, because it is true that these must be the forces which do really act. Different pressures produce different accelerations upon the same mass; or to one acceleration there is but one producing pressure, the mass being given. But it may happen that the forces actually *impressed*, or the pressures actually employed, at the point P, may be very different from those which just produce the motion that is produced. Suppose for example that the mass P were attached to the mass Q by the rigid rod P Q without weight; and suppose such forces to be applied at P and Q as, whatever may become of Q, cause P to move uniformly along the parabola in the manner above described. We may assign an infinite number of different motions to Q, and for each motion of Q we may assign an infinite number of pressures which, being applied to P and Q, will give the two their supposed motions. But in no one of these cases can the total amounts of pressure really applied to P, in the directions of x and y, be any other than those which are calculated above: whatever may be the pressures actually applied at P, the thrust or pull, as the case may be, of the rod P Q, will supply what is necessary to make all the forces that act on P (those directly applied and that arising from the said thrust or pull) together equivalent to the pressures above calculated. This is the foundation of *D'Alembert's principle.* [FORCES, IMPRESSED AND EFFECTIVE; VIRTUAL VELOCITIES.]

The connection between velocity and pressure is not only obscured by phrases as cloudy as "moving force," but also by the use of the unit of mass instead of the unit of weight. This measurement by masses instead of weights is so convenient and so desirable on rational grounds, that it cannot ultimately be dispensed with; but at the first outset the student should be taught to reduce the new mode of proceeding into terms of that with which he is then better acquainted. A beginner in the theory of gravitation is not allowed to have the least idea of the amount of the attractions of the several bodies upon each other in pounds or tons, or any other unit which he can at once understand. And we should not be surprised if many who can easily compare the sun's attraction upon the earth with the earth's attraction upon the moon, so as to find either of them when the other is given, would be awkward at, if not actually puzzled by, the question of comparing either of them with the weights in a grocer's shop. Undoubtedly there would not be much of astronomical utility in the question; but for clear conception of the meaning and mode of derivation of mechanical results, nothing can be of more importance than the actual comparison of all results with those which are best known, because actually felt and perceived.

VELVET, a variety of manufactured silk, remarkable for the softness of its surface. Velvet was unknown at least several centuries after the introduction of plain woven silks; and it is not mentioned in any documents earlier than the 13th century. For a long time the manufacture was confined to Italy, where, particularly in Genoa, Florence, Milan, Lucca, and Venice, it was carried on to a great extent. It was subsequently introduced into France, and brought to great perfection. On the revocation of the Edict of Nantes, in 1685, this branch of weaving was begun in England by the refugees.

The peculiar softness of velvet is owing to a loose *pile* or surface of threads, occasioned by the insertion of short pieces of silk thread doubled under the shoot, weft, or cross threads. These stand upright so thickly as entirely to conceal the interlacing of the warp and shoot. The richness of the velvet depends upon the closeness of the pile-threads. The insertion of these short threads is effected in the following manner:—Instead of having only one row of warp-threads, which will be crossed alternately over and under by the shoot, there are *two* sets, one of which is to form the regular warp, while the other is to constitute the pile; and these two sets are so arranged in the loom as to be kept separate. The quantity of the pile-thread necessary is very much more than that of the warp-thread; and, therefore, must be supplied to the loom by a different agency. If the pile-threads were worked in among the shoot in the same way as the warp-threads, the fabric would be simply a kind of double silk, but without any pile. The pile-threads are, therefore, formed into a series of loops, standing up from the surface of the silk, and by subsequently cutting these loops with a sharp instrument, the pile is produced. The loops are formed in a very singular way. After the weaver has thrown the shuttle three times across, making the shoot interlace three times among the threads of the warp, he inserts a thin straight brass wire at right angles to the length of the piece, or parallel with the shoot. The wire is so placed as to occupy a position through the whole breadth of the fabric, above the warp-threads and below the pile-threads. The treadle is then put to work, the alternate threads of the warp raised, and the shuttle again thrown; by which a shoot-thread is thrown *over* the pile-threads, and also over one-half of the warp-threads; the wire becomes thus, as it were, woven into the substance of the fabric. Two more traverses of the shoot are then made, passing alternately under and over the warp threads in the usual way, but not interfering with the pile-threads. Another wire is then laid in, below all the pile-threads and above all the warp-threads, and this is secured by subsequent shoot-threads, as in the first case. By a delicate and difficult process, these wires are removed by the same operation which produces the raised pile. Each wire is nearly a semicylinder in form, and has along its upper surface a carefully constructed groove; along this groove the weaver passes the sharp edge of a cutting instrument called a *trevat*, severing the pile-threads in his progress. It necessarily follows from this operation that two ends of each thread are thus loosened; and these ends, being afterwards brushed up and dressed, constitute a portion of the pile, sufficiently long to hide completely the woven fabric beneath. Two wires are employed, because if one only were used, the pile-threads would become disarranged when it was removed. When the liberated wire has been again inserted, and three shoots thrown to secure it, the second line of loops is cut and the second wire removed; and so on during the weaving of the whole length.

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* We have not entered into the distinction of meaning between positive and negative velocities and accelerations, since the question is a purely algebraical one, unnecessary to be treated here if the student really understand algebra, and impossible to be explained within our limits to one who does not.

* The weight has been throughout supposed to be neutralised, as it would be if the parabola were in the plane of a table, on which the particle is laid.

Striped velvets are produced by some of the pile-threads being uncut. The slowness and delicacy of this branch of manufacture may be judged from the fact that forty or fifty insertions of the grooved wire are made in the space of one inch, the loops of the pile being cut an equal number of times. In addition to the other complications, the weaver has to use two shoot-threads, and consequently two shuttles; for the shoot thrown immediately after the insertion of the wire is stouter than the two following. It is considered to amount to a good day's work when one yard of plain velvet has been woven. Cotton is now employed, as well as silk, in the manufacture of velvet. The different varieties of fustian are a kind of cotton-velvet.

Among recent inventions in the velvet manufacture, one, by Mr. Gratrix, is applicable to velvets in which the pile is produced by the weft, and the cut made in the direction of the warp. The pile-threads are woven on a series of fine longitudinal knives with elongated points. The knives are stationary, and have their cutting ends attached to a bedding-frame. Simultaneously with the weaving, the portions of weft intended to form the pile slide consecutively upon the points of the knives as the cloth is woven; and the weft, when it arrives at the cutting portions of the knives, is severed. Another arrangement, by the same inventor, is for severing the pile without cutting at all. Wires are woven in with the threads, so as to leave the pile above them; they pass between two peculiarly-formed rollers, which press open the fibres over each wire, and thus liberate all the wires. Some of the processes recently introduced enable the weaver to cut and emboss the velvet at the same time.

VENA CONTRACTA. [Hydrodynamics.]

VENDOR AND PURCHASER. The law of vendors and purchasers of real estate in England is a subject of great extent, which may be said to comprise nearly the whole practical application of the law of real property.

Contracts for the sale and purchase of land or other real estate may be entered into either privately between the parties, or upon a sale by auction. At common law, agreements for the purchase of real estates might be made by parol, but by the Statute of Frauds (29 Car. II. c. 3, ss. 1, 2, 3, and 4), "All leases, estates, interests of freeholds, or terms of years, or any uncertain interest of, in, or out of any messuages, manors, lands, tenements, or hereditaments, made and created by livery and seisin only, or by parol only, and not put in writing by the parties so making or creating the same, or their agents thereunto lawfully authorised by writing, shall have the effect of leases or estates at will, any consideration for making any such parol leases or estates notwithstanding." But leases not exceeding three years, whereupon the rent reserved should amount to two-thirds of the full improved value, are excepted. The act requires the assignment, grant, and surrender of existing interests to be in writing, and enacts that "no action shall be brought whereby to charge any person upon any agreement made upon any contract or sale of lands, tenements, or hereditaments, or any interest in or concerning them, unless the agreement upon which such action shall be brought, or some memorandum or note thereof shall be in writing, and signed by the party to be charged therewith, or some other person thereunto by him lawfully authorised." The note or memorandum of agreement required by the statute need not be a formal document, and any writing, such as a letter, or receipt for purchase-money, may constitute an agreement within the statute, provided it contain the terms of the agreement within itself, or by reference to another writing; and if the document be written by the party, the occurrence of his name anywhere in the document is a sufficient signing.

Upon sales of estates by public auction, the highest bidder, upon being declared the purchaser, is considered to have entered into a contract for purchase according to the particulars and subject to the conditions of sale; and the auctioneer, who is for this purpose considered as the agent of both vendor and purchaser, is thereupon authorised to sign an agreement of purchase. The writing down the purchaser's name upon any memorandum of sale at the time of the bidding is a sufficient signing. Sales by auction of lands are within the above-mentioned enactments of the Statute of Frauds; but sales before a master under a decree of a court of equity will be carried into execution although the purchaser did not subscribe any agreement, for the judgment of the court in confirming the purchase takes it out of the statute. The subject of the sale and purchase of estates is discussed at length in Sugden's (now Lord St. Leonards) and Dart's 'Treatises on the Law of Vendors and Purchasers of Estates.'

VENEERING, in cabinet-work, is the art of laying thin leaves, called *veneers*, of a valuable kind of wood upon a ground or foundation of inferior material, so as to produce articles of elegant appearance at smaller cost than if they were made solid, or composed entirely of the ornamental wood which appears on the surface. Small veneers are cut by hand with a thin saw, the block being held firmly in a vice; but large ones are usually cut by machinery, for a notice of which see Saw-Mill. They are carefully brought to the right thickness by fine planes; cut precisely to the required shape; and then glued down to the ground, which should be of dry wood, with strong glue. If the form of the article will permit, it is then put in a press until the glue is dry; but if not, the newly-laid veneers are covered with a board, which is pressed down either by weights or by poles abutting against the beams in the roof of the workshop. In veneering on curved surfaces a somewhat different course is pursued, but with the same object, that of keeping the veneer in its place until the glue is sufficiently set to hold it securely. The work is afterwards finished with very fine planes and scrapers, and polished with fish-skin, wax, and a brush or polisher of shavegrass.

It may here be mentioned, that before the saw-mills were rendered applicable, the elder Brunel devised a mode of cutting timber into veneers by a kind of knife. This knife was formed of several pieces of steel, exactly in a line on their lower surface. The block of wood was carried sideways beneath the knife by a screw slide, worked by a handle, and the knife cut it by a short reciprocating or sawing action. The block was raised, after each cutting, to a height equal to the thickness of the required veneer. The method answered well for straight-grained and pliant wood, such as Honduras mahogany, but not for other kinds.

Ivory veneers, or rather thin sheets for miniatures and for memorandum books, are sometimes not more than one-sixtieth of an inch in thickness, requiring much nicety in their manipulation. [Ivory.] *Vulcanite*, or vulcanised india-rubber, is now used as a veneer. It is rolled into thin sheets, which may be either plain or embossed, and it receives a polish by the rolling. In applying this substance as a veneer, the sheets are dipped for a few minutes in boiling water, till they become as tractable as moist paper; and the workmen can then veneer with them round and over the sharpest curves and angles. Ordinary wood veneers cannot well be bent round corners; a patent to effect this has been taken out by Mr. Meadows; but in general it is not attempted.

The Americans have recently introduced, under the name of *pressed work*, veneering of a remarkable kind. Instead of a thin veneer being placed upon a thicker substratum, the whole substance consists of veneer. It comprises four, six, eight, or any other number of layers. Some strong plain wood, such as black-walnut, is selected for the interior layers, and rosewood or other fancy wood for the exterior. The veneers, which are of the usual thickness, are well saturated with glue, and placed one upon another, with the grain of each layer at right angles to that of the next. The mass, while hot, is placed in moulds, named *cauls*, and pressed forcibly for twenty-four hours. When taken out, the wood is found to be firm, elastic, and strong, and to conform to any curvature which the mould may have given to it. On account of the crossing of the fibres, the wood can scarcely split, except by a force that would rend it to pieces. The pores have become so filled with glue, as to add in a remarkable way to the strength of the substance. Mr. Belter introduced this art; and at the present day, pressed-work is very much used in the United States for the better kinds of furniture. Chairs of this make are in demand, for their great strength and remarkable lightness; it is the *back* of the chair, generally elegantly curved, that consists of pressed work. There are usually seven layers for the back of a chair, making a substance surprisingly thin in relation to its strength. An odd number of veneers is usually selected, in order that the grain may extend in the same direction on both surfaces. The frame-work for bedsteads is formed in a similar way; and so are the bodies of such musical instruments as the violin and violoncello. M. Bogaud, another inventor, has succeeded in producing *dished* or *spheroidal* pressed work: that is, articles in wood presenting much deeper curves than those just described. To effect this, the veneers are cut by machines into stripes, each of which varies in width according to the part of the mould into which it is to be pressed; the cutting must be very accurate to effect this, and can only be done by apparatus mathematically adjusted. A curve of double curvature may be produced by this method. Hitherto, this dished pressed work has necessarily been very expensive.

We must notice also M. Amies' method of veneering in relief. Two moulds, an upper and an under, as in cameo and intaglio, are gently heated, and a sheet of veneer is placed between them. One side of the veneer takes the device in relief; the other side, hollow, is then filled up with mastic or any plastic substance. The veneer is in the first instance smoothed or polished on the surface which is to be in relief. Paper is pasted on the back; and it is while the wood is yet damp with the paste that it is pressed between the dies; the paste assists the veneer to conform to the dies, and to retain the device when cold. The veneer is not removed from the mould till quite dry. Medallions are produced in this way, remarkable for the sharpness and perfection of the device.

VENETIAN SCHOOL OF PAINTING. [PAINTING.]

VENIRE FACIAS, or *Venire*, the name of a writ addressed to the sheriff or other returning officer, commanding him "to cause to come" (*venire facias*) the parties set forth at the place named in the writ. The purpose to which the writ was formerly applied, and in reference to which it is generally known, is in summoning juries to serve for the ordinary trial of civil causes. It has long ceased to be acted upon, the court assuming that the jurors had been summoned upon it and had failed to appear at Westminster, where anciently the trial itself took place, another writ thereupon issuing to bring them to the assizes. Now, however, the sheriff is simply commanded to summon the jurors to appear before the judges of Assize or Nisi Prius. (*Common Law Procedure Act*, 1852.) [JURY; VENUE.]

VENTILATION. [WARMING AND VENTILATION.]

VENTRE INSPICIENDO, WRIT DE. "When a widow is suspected to feign herself with child in order to produce a suppositious heir to the estate, the heir presumptive may have a writ *de ventre inspiciendo*, to examine whether she be with child or not; and, if she be, to keep her under proper restraint till delivered; which is entirely conformable to the practice of the civil law: but if the widow be, upon due examination, found not to be pregnant, the presumptive heir shall be admitted to the inheritance, though he hath to lose it again, on the birth of a child within forty weeks from the death of a husband." (Blackstone, 'Comm.' i. 456) The Roman practice is explained in the title of the 'Digest' (25 tit. 4): "*De inspiciendo ventre custodiendoque partu.*" The practice originated in the joint reigns of Aurelius and Verus, in a case in which a wife denied her pregnancy and the husband maintained it. The wife had separated from the husband, and probably wished to keep the child that might be born, though by law it would belong to the husband. If a woman alleged that she was left pregnant by her deceased husband, it was her duty to announce the fact to those whom it concerned, and to inform them that they might, if they pleased, send women to inspect her (*quæ ventrem inspiciant*). All the proceedings of inspection and of watching the woman, if she should be reported to be with child, are minutely prescribed in the Prætor's Edict. The penalty in case of the woman not complying with the edict was, that the prætor would refuse to the child the *bonorum possessio*.

The form of the English writ *de ventre inspiciendo* is given Co. Litt. 8 b. It is directed to the sheriff, and commands him to empanel a jury of twelve women to search whether she be enceinte. If they find that she is with child, another writ issues which commands that she shall be safely kept and duly inspected by the women, who must be present at the delivery.

The use of this writ is an instance in which what is called a proceeding at common law is taken from the Roman system. (Co. Litt. 8 b., and N. 44 in Butler's edition; Comyns, 'Digest,' Bastard, C.)

VENTRILOQUISM (literally "belly-speaking:" from *venter*, the belly; and *loquor*, I speak) is a vocal mimicry of sounds, by which an illusion is produced on the hearer that the sound comes, not from the mimic, but from some other appropriate source. The various phenomena of vocal mimicry may be conveniently considered under two general heads, namely: 1st, The simple imitation of the voices of persons, of animals, of musical instruments, and other sounds and noises of every description, in which no illusion is intended, but, on the contrary, the imitation avowedly and perceptibly comes from the mimic; and 2nd, The imitation of those voices, sounds, and noises, not as originating in the mimic, but in some other, an appropriate source at a given or varying distance, in any or even in several directions successively. And when these imitations are made without moving the mouth, features, or body, the illusive effect of the mimicry is enhanced. The terms mimicry, or imitation, are commonly adopted to designate efforts under the former general head where no illusion is intended, while the term ventriloquism distinguishes those under the latter where an illusion is produced.

The various kinds of divination amongst the nations of antiquity which were stated by the priesthood to be by a spirit, a familiar spirit, or a spirit of divination, are now supposed to have been effected by means of ventriloquism. Divination by a familiar spirit can be tracked through a long period of time. By reference to Leviticus, xx. 6, 27, it will be seen that the Mosaic law forbade the Hebrews to consult those having familiar spirits, and to put to death the possessor. The Mosaic law was given about fifteen hundred years before Christ. Divining by a familiar spirit was however so familiar to the Jews, that the prophet Isaiah draws a powerful illustration from the kind of voice heard in such divination, see Isaiah, xxix. 4. In the Acts of the Apostles, xvi. 16, mention is made of a young woman with a familiar spirit meeting the Apostles in the city of Philippi in Macedonia. And St. Chrysostom and other early fathers of the Christian Church mention divination by a familiar spirit as practised in their day. The practice of similar divination is still common in the East, and is even practised amongst the Esquimaux. This divination by a familiar spirit has been practised upwards of three thousand years.

The witch of Endor divined by a familiar spirit; 1 Sam. xxviii. 7, in Hebrew אוֹב—(Ob.) The word is also adopted in the Hebrew Bible to designate those persons, whether male or female, in whom there is a familiar spirit. The plural of אוֹב is אֹבוֹת—Oboth, which in the Septuagint version of the Scriptures is mostly rendered by the Greek Ἐγγαστριμύθους, which is compounded of *ἐν*, in, *γαστήρ*, the belly, and *μῦθος*, speech, and corresponds with the word ventriloquism. The rendering of the Hebrew in the Septuagint, Professor Lee accounts for by the muttering of those having a familiar spirit—the אֹבוֹת: see his Hebrew Lexicon, or 'Thes. Heb.' Gesenii, *sub voce*.

The Greeks practised a mode of divination termed gastromancy, from *γαστήρ*, the belly, and *μάντις*, a prophet; where the diviner replied without moving his lips, so that the consulter believed he heard the actual voice of a spirit speaking from its residence within the priest's belly. St. Chrysostom adopts the same Greek word as the translators of the Septuagint version to designate the diviners by familiar spirits, namely, Ἐγγαστριμύθους.

The earliest description of a ventriloquial illusion in modern days is that performed by Louis Brabant, valet-de-chambre of Francis I. By the aid of ventriloquism he extorted from the mother of a young woman her consent to their marriage which she had previously opposed, and from a rich old man a large sum of money. The work of M. l'Abbé de la Chapelle, published 1772, descriptive of the feats of Baron Mengen at Vienna, and of M. St. Gille near Paris, claims attention. Baron Mengen made a doll with moveable lips, which he could control by his hand under its dress. With this doll he held witty and satirical dialogue. Baron Mengen said he owed his art to a passion for counterfeiting the cries of animals and the voices of persons, that the passion manifested itself in early life; and that he had the power of imitating sounds so accurately as to make them appear to come from other places than his own mouth.

M. St. Gille, in 1771, made an experiment to test his ventriloquial talent before MM. Leroy and Fouchy, commissioners of the Royal Academy of Sciences, and many other persons of the highest rank. The object of the experiment was to show that M. St. Gille's mimicry of sounds was so perfect as to produce illusion. For this purpose it was reported that a spirit's voice was at times heard in the environs of St. Germain, and that the commission was appointed to verify the fact and to discover the cause. All the company were in the secret except one lady, who, without suspecting it, was to be the subject of the illusion. They all dined in the country in the open air, and while they were at table a voice, as of a spirit suspended in the air, addressed the lady: now it seemed at the top of the trees; then descending, it approached her—then receding, it plunged into the ground, whence it ceased not to make itself heard. The conversation was sustained upwards of two hours with such adroitness that the lady was fully convinced she had talked with a sylph; and when the illusion was explained to her, she doubted if it were an illusion.

M. St. Gille, like Baron Mengen, made no secret of his art, but referred it all to mimicry, for which he had a strong propensity. The French Academy adopted the views contained in the statements of these two ventriloquists, namely, that the art consists in an accurate imitation of any given sound as it reaches the ear.

Adopting these views, physiologists have offered a variety of possible actions of the vocal organs to explain its production; and some have even supposed a peculiarity of structure of the vocal organs as necessary, but have wisely omitted to specify what. Many physiologists think that ventriloquism is vocally produced by speaking during inspiration of the breath. It is possible to speak during inspiration, and it may be occasionally adopted; but close observation on many public ventriloquists, and private friends who can ventriloquise, convinces the author of this article that the general current of utterance is, as in ordinary speech, on an expiration of the breath.

Adopting the views of the French Academy, some have thought that the vocal means of effecting the required imitation consist in a skilful management of the echoes of sound. Unfortunately, however, for this theory, an echo merely repeats what is already produced; and several ventriloquists, including the late Mr. Mathews, have produced the vocal illusion while walking in the streets.

Baron Mengen thus describes his mode of speaking when the voice was to seem to come from his doll:—"I press my tongue against the teeth, and thus circumscribe a cavity between my left cheek and teeth, in which the voice is produced by the air held in reserve in the pharynx (*gosier*). The sounds thus receive a hollow and muffled tone, which causes them to appear to come from a distance." The Baron says it is necessary to well manage the breath, and to respire as seldom as possible.

It was observed that M. St. Gille appeared fatigued after long exertion, when the vocal illusion became less perfect. Those ventriloquists with whom the author of this article has conferred have acknowledged fatigue in the chest, which they have attributed to the extremely slow expiration of the breath. M. St. Gille, like most professional ventriloquists, was observed to cough very frequently.

Now, in order to arrive at exact and positive knowledge of the modifications of voice termed ventriloquism, it is necessary to be familiar with the distinctions of vocal sound; and to know how the organs act in producing those vocal modifications, it is necessary to know how the breath is vocalised in all its distinctions of pitch, loudness, and quality, by the ordinary actions of the vocal organs.

In ordinary language we speak of noise, of sound, and of musical sound; and Dr. Thomas Young adopts those terms in illustrating the mechanical causes of sounds:—"A quill striking against a piece of wood causes a noise; but striking successively against the teeth of a wheel, or of a comb, a continued sound; and if the teeth of the wheel are at equal distances, and the velocity of the rotation is constant, a musical sound." ('Lect. Nat. Phil.')

The general terms pitch, loudness, quality, and duration embrace all the distinctions which the musician discovers in musical sounds, and which he employs in his art. The distinguishing feature of musical sound is its uniform pitch throughout its duration. And, acoustically musical sound is composed of an equal number of impulses or noises produced in equal times. [Acoustics; Voice.]

The general terms pitch, loudness, quality, and duration also embrace all the distinctions heard in ordinary sounds. These sounds differ from the musical in the pitch constantly varying throughout their duration, as the human voice in speaking, and the voices of quadrupeds. Acoustically, such sounds are composed of an unequal number of impulses or noises produced in equal times. And from this circumstance pitch, in the strictly musical sense, is not a property of ordinary sound.

The general terms loudness and quality embrace all the distinctions heard in a noise, as in the collision of two inelastic sticks. The momentary collision of the clapper against a bell is a noise, but this mere noise is immediately followed by the ringing sound of the bell, which is a musical sound. Pitch and duration can scarcely be considered as belonging to common noise. Thus we have:—

I. Noise, whose audible distinctions are comprehended under the general terms loudness and quality.

II. Common sound, whose audible distinctions are comprehended under the general terms loudness, quality, duration, and ever-varying pitch.

III. Musical sound, whose audible distinctions are comprehended under the general terms loudness, quality, duration, and an uniform pitch.

Phonation, or the production of voice, is a result of actions taking place under two distinct classes of laws, namely: 1. The ordinary mechanical laws of acoustics; and 2. The physiological laws of muscular movement. The adjustment of the vocal mechanism to be acted on by the current of air is made by actions under the latter laws; and phonation is the result of the re-action of the mechanism on the current of air, by mechanical movements under the former laws. [Larynx, in Nat. Hist. Div.] The pitch of the voice essentially depends on the tension of the vocal ligaments; the loudness on the extent of excursion of the vocal ligaments in their vibration; the duration on the continuance of the vocalising causes; and the quality on the organisation of the larynx, and also on the form and size of the vocal tube. Now the form and size of this tube can be altered in various ways, as by dilating or contracting the pharynx [Pharynx, in Nat. Hist. Div.]; by dilating or contracting the mouth; by contracting the communication between the pharynx and mouth so as to make them distinct chambers, or by dilating the opening so as to throw them into one, which is chiefly effected by movements of the soft palate; by altering the form of the mouth's cavity, which is produced by varying the position of the tongue. It will be found that each of these modifications of the vocal tube confers a peculiarity of quality to the voice. All these, however, are vocal or laryngeal sounds.

Sounds can be produced in the vocal tube apart from the larynx. These are not vocal sounds. Some of them, however, may be of a definite and uniform pitch, while others are mere noises, as rustling, whispering, gurgling, whistling, snoring, and many others.

Now, as every audibility comes under the classes of noise, sound, or musical sound, and as each variety under these classes is producible by the vocal apparatus of man, it is an obvious conclusion that an ordinary vocal apparatus is all that is required to vocalise the mimetic conceptions of the ventriloquist. A larynx capable of producing a larger compass of voice than another has a greater range of pitch within its power of imitation.

A person having an ear acutely perceptive to the nice distinctions of sounds may, by a little practice, imitate many sounds with accuracy. Those persons, however, who are highly endowed with the mental requisites, which consist of an intense desire to mimic, coupled with the ability to originate mimetic ideas, are able to imitate sounds at first hearing, and without previous practice. Passing from the imitation of sounds, as that of knife-grinding, sawing and planing wood, the voices of animals and men, we proceed to treat of those illusions where the voice so perfectly counterfeits the reality intended, that it appears not to issue from the mimic, but from an appropriate source, in whatever direction and at whatever distance that source may be. The essence of ventriloquy consists in creating illusions as to the distance and direction whence a sound has travelled; which are thus explained:—

I. *Distance.* We do not hear the distance which a sound has travelled from its source, but we judge the distance from our former experience, by comparing the loudness which we hear with the known distance and known loudness of similar sounds heard on former occasions. Common experience will confirm, that we oftener err in estimating the distance of uncommon than of familiar sounds. In apology for such an error the ordinary language is, "It seemed too loud to come so far," or "It seemed too near to be so faint a sound," as the case may be. Both of which are apologies for an erroneous judgment, and not for hearing.

Near sounds are louder than distant ones. Now, by preserving the same pitch, quality, and duration, but with an accurately graduated reduction of loudness, a series forming a perspective (if the term be allowable) of sounds may be created, which, falling in succession on the ear, will suggest to the mind a constantly increasing distance of the sound's source.

Loudness is a property of sound which has not had justice done to its importance in the schools of music and elocution. Its nomenclature is vague and meagre, and it can scarcely be said to have a notation. The author of this article has observed that one of the high excellences which singers of genius have snatched beyond the rules of art has been a skilful management of the degrees of vocal loudness, and a nice adaptation of them to aid the melody in expressing the intended feeling. The varieties of loudness remain still unmeasured, and the abrupt transitions in loudness made by musical performers suggest that these distinctions are ill perceived.

The estimate, then, which is formed of the distance which a sound has travelled before reaching the ear is a judgment of the mind formed by comparing a present perception (by hearing) with the remembrance of a former loudness in connection with its known distance.

II. *Direction.*—The direction whence a sound comes seems to be judged of by the right or left ear receiving the stronger impression, which however can only take place when the sound's source is in a plane, or nearly so, with a line passing through both ears. It is familiarly known that a person in a house cannot by the noise of an approaching carriage judge with certainty whether it is coming from the right or left. He accurately judges it to be approaching, passing, or receding, as the case may be, by the gradations of loudness, but is unable to decide with certainty whether its approach or recession is from up or down the street. Common experience shows the judgment to be more fallible concerning the direction than the distance of sounds. Professor Müller of Berlin states, in his 'Physiology,' that Venturini's experiments, detailed in Voigt's 'Mag.,' bd. ii., demonstrate the impossibility under certain circumstances of estimating whence a sound comes to the ear. Now, without entering upon the merits of those valuable experiments, enough has been above stated to show that we do not hear, but that we judge, the direction a sound has travelled from its source on reaching the ear.

It has been remarked, and the writer of this article confirms its truth from observations made both in public and in private ventriloquy, that the ventriloquist indicates either directly or indirectly the direction which he wishes his audience to believe the sound is coming. Thus they directly indicate it by words, such as—"Are you up there?" "He is up the chimney," "He is in the cellar," "Are you down there?" &c. And they indirectly indicate it by some suggestive circumstance, as an action or gesture which is so skilfully unobtrusive and natural as to effect its object without being discovered. Thus, when the ventriloquist looks or listens in any direction, or even simply turns towards any point, as if he expected sound to come thence, the attention of an audience is by that means instantly directed also to the same place. Thus, before a sound is produced, the audience expect it to come in the suggested direction. And the ventriloquist has merely, by his adjustment of vocal loudness, to indicate the necessary distance, when a misjudgment of the audience will complete the illusion which he has begun.

The effect which is produced on sound by its travelling from a distance is observed to be—

1. That its loudness is reduced in proportion to the distance.
2. That its pitch remains unaltered.
3. That its quality or tone is somewhat softened.
4. That its duration remains unaltered.
5. That human speech is somewhat obscured, chiefly in the consonant sounds.

Now, the ventriloquist imitates the sound, not as it is heard at its source, but as it is heard after travelling from a distance. A skilful ventriloquist can effect his imitations without much movement of his lips and features. Now, it has been observed that ventriloquists, during their efforts, turn the front face away from the audience and scarcely even show the profile. The author of this article confirms this observation, as far as regards moderate-sized rooms, but he has seen the front face in a theatre.

It is quite easy to speak without moving the jaw, and it is the jaw's movements which disturb the features in utterance. Now the labial sounds, such as B, P, M, when the jaw is thus fixed, can be made with a slight movement of the lips. The lips and jaws being always somewhat open during ventriloquy, a slight labial movement remains unnoticed, unless special attention be directed to it; and all the modifications of voice can be produced without at all distorting the features or moving the lips.

The preceding outline of the philosophy of ventriloquism is sufficient to exhibit the nature of the art. To enter upon the consideration of all the vocal means adopted to accomplish the various imitations would fill a volume. The mode of counterfeiting variations in loudness by changes of pitch, and also by changes from the natural to the falsetto register of voice, are amongst the wonders of vocal science, and are capable of extensive application by the scientific ventriloquist.

VENUE (*vicinetum*, *visne*, "neighbourhood"). The county in which the trial of a particular cause takes place is said to be the venue of that cause. The old practice in this matter is connected with the original functions of the jury, as persons who were acquainted with the facts in issue. [JURY.] In order, then, that a proper *venire* might issue to the sheriff, the place in which the action was brought was stated in the margin of the declaration, and on the statement throughout the pleadings of any issuable fact a statement was also made of the place at which such fact was alleged to have occurred. As to all such facts upon which issue was taken, a *venire* was sued out applying to each different place. The sheriff returned jurors from that place, and by those jurors the facts were decided, so that several distinct *venires* and trials might be necessary to dispose of the issues in one action.

When juries ceased to act on their own knowledge, and began to determine on the evidence of witnesses, the necessity ceased for summoning them from the particular part of the country, and the practice gradually declined, till at last, the *venire* itself gave way to a precept commanding the attendance of the jurors at the assizes. (*Common Law Procedure Act*, 1852.)

A distinction was long since established between local actions (that is, actions relating to real estate) and transitory (that is, actions of debt, contract, for personal injuries, &c.). In regard to the former, it was held that the actual place in which the subject-matter was situated must be laid as the venue in the action, and that rule still prevails. The reason is said to proceed from the circumstance that, unless the action were brought in the actual county, the sheriff of the county would be unable to give effect to the judgment in the action. In transitory actions, on the contrary, the subject-matter of them being held not to have any fixed place, the plaintiff is at liberty to bring his action in any county in which he please. As a consequence of which it follows, that though the cause of action has occurred even out of the kingdom, it is still open to the plaintiff to bring his action in the courts of this country. The plaintiff has still this liberty in a transitory action; but the courts assert an authority upon application made to them of changing the venue. This is done upon its being made to appear that great inconvenience would arise from trying in the original county, because the body of the evidence lies in another, or because from local prejudices a fair trial cannot be had, &c. And the same authority may be exercised even in local actions, in spite of the technical difficulty which has been before referred to.

In criminal trials the venue is usually the county in which the offence charged was actually committed. The courts however have the same discretion as to the power of changing the venue as in civil cases; and as to criminal trials, many exceptions have been introduced by various statutes.

VENUS DE MEDICI. [APHRODITE.]

VENUS, the name of the planet which is nearest to the earth, and, except Mercury, nearest to the sun. The principal point of its physical description is the distinctness with which its phases are seen through a telescope, in which it exhibits all the changes of appearance which are, to the naked eye, characteristic of nothing but the moon. With regard to these phases, there is a remarkable historical error which we cannot trace higher than Dr. Smith's 'Optics,' but which has been copied by Hutton and others. It is said, "When Copernicus revived the ancient Pythagoric system, asserting that the earth and planets moved round the sun at the centre of their orbits, the Ptolemaics objected, if this were true, that the phases of Venus should resemble those of the moon. Copernicus replied, *that some time or other that resemblance would be found out.*" (Smith's 'Optics,' p. 415.) Now, first, Copernicus never answered an objection to his system in the manner implied in the story; for he literally only lived to lay his hand upon a copy of his own work, and never opened it. [COPERNICUS, in BIOG. DIV.] Secondly, Gassendi, his biographer, in stating the verification of his system (as he calls it), derived from these phases, never alludes to any such prophecy; nor does Galileo, in announcing the telescopic discovery of the phases of Venus (A.D. 1611), and in giving praise to Copernicus and Kepler for not having abandoned the motion of the earth on account of the difficulty arising out of the apparent want of them, ever suppose that Copernicus, or any of his followers, had the slightest idea of that apparent want arising from imperfection of vision. Thirdly, Copernicus himself, in mentioning the difficulty, expressly meets it by the supposition that Mercury and Venus, the "stellæ" alluded to in the coming quotation, either shine by their own light, or are completely saturated with the solar rays: "Non ergo fatemur in stellis opacitatem esse aliquam, lunari similem, sed vel proprio lumine, vel solari totis imbutas corporibus fulgere, et idcirco solem non impedire" (lib. i. cap. 10). And the objection itself has nothing to do with the difference between the system of Copernicus and that of Ptolemy, for it had long before been raised against the latter: all, in fact, who maintained that the orbit of Venus comes between the earth and sun having to meet it in one way or another, whether they made the earth or the sun the centre of their system.

In the theory of the motion of Venus, the most remarkable circumstance is the *long inequality* discovered some years ago by Mr. Airy, depending upon the earth. [GRAVITATION.] A satellite was at one time suspected to belong to this planet, but no such thing has ever been detected. It may be remarked that the satellite of an inferior planet might not be easy to find, if it were very small; for when the planet is nearest the earth, and circumstances are most favourable for its discovery in other respects, the dark side would be turned towards the earth. Though in the earlier period of telescopic observations, spots of various sorts were detected on the disc of Venus, yet the general description of its appearance in our day, as given by Sir J. Herschel, is as follows:—"Although it occasionally attains the diameter of 61", which is larger than that of any other planet, it is yet the most difficult of them all to define with telescopes. The intense lustre of its illuminated part dazzles the sight, and exaggerates every imperfection of the telescope; yet we see clearly that its surface is not mottled over with permanent spots like the moon; we perceive in it neither mountains nor shadows, but a uniform brightness, in which sometimes we may indeed fancy obscurer portions, but can seldom or never rest fully satisfied of the fact. The most natural conclusion, from the very rare appearance and want of permanence of the spots, is, that we do not see, as in the moon, the real surface of this planet, but only its atmosphere, much loaded with clouds, and which may serve to mitigate the otherwise intense glare of its sunshine."

Venus, like Mercury, from the orbit being entirely within that of the earth, is never at more than a certain angular distance from the sun; her greatest angular distance, or elongation, being from 45° to 47° 12′. Her mean apparent diameter is 16″·9, but varies from 9″·6 to 61″·2. The real diameter is ·975 of that of the earth, or about 7700 miles, and the volume is ·927 of that of the earth. The density is very nearly that of the earth; but this element, as also the mass, is rather uncertain. The mass of this planet is stated by Laplace at $\frac{1}{356632}$th of that of the sun, but later writers give $\frac{1}{405871}$th as more probable. Mr. Rothman ('Mem. Astron. Soc.,' vol. xii. pp. 409-415) has shown strong reasons for supposing that the mass given by Laplace has been too much diminished by his successors, and that the second fraction above named should be increased by about its tenth part at least, and probably by more. The most uncertain of all the results of the theory of gravitation is the mass of a planet which has no satellite.

This planet revolves on its axis in about $23^h\ 21^m\ 7^s$; though this, owing to the absence of definite spots on its disc, can hardly be considered as very accurate. Its light and heat are to that of the earth as 1911 to 1000.

The elements of the orbit of Venus, which are usually taken from Lindenau's Tables (1810), have lately undergone a searching examination by comparison with seven years' observations made at Greenwich. Messrs. Main and Glaisher, who made this examination, have given their own resulting elements, compared with those deduced for their own epoch, from the above-mentioned tables. In the following list we have adopted the new elements, placing the old ones after them in parentheses; but taking the secular variations entirely from those given as the result of the investigation just quoted ('Mem. Astron. Soc.,' vol. xii.). The semiaxis major alone remains untouched; for though the examiners found reason to suspect that it was somewhat in error, they did not feel able to decide with certainty as to the amount of the alteration.

Elements of the Orbit of Venus.

Epoch 1836, January 1, 0^h mean astronomical time at Seeberg ($42^m\ 56^s$ east of Greenwich).

Semiaxis major ·7233316, that of the Earth being assumed as the unit.

Eccentricity ·00684568 (·00682265); its secular diminution (or diminution in 100 years), ·00008200.

Inclination of the orbit to the ecliptic, 3° 23′ 34″·34 (3° 23′ 31″·11); its secular increase, 10″·035.

Longitudes from the mean equinox of the epoch (1) of the ascending node, 75° 12′ 3″·60 (75° 12′ 25″); its secular increase (combined with the precession), 3095″·23: (2) of the perihelion, 129° 15′ 3″ (129° 11′ 18″); its secular increase (combined with the precession), 49″·62; of the planet (mean), 332° 1′ 35″·23 (332° 1′ 33″·1).

Mean sidereal motion in 365¼ days, 2106641″·49; sidereal revolution, 224·7007869 mean solar days.

When Venus is to the west of the sun she rises and sets before him, and was then called Phosphorus and Lucifer by the ancients; but when she is to the east of the sun she rises and sets after him, and was then called Hesperus. The old terms of our almanacs, "Morning-star" and "Evening-star," have reference to these positions.

VENUS, TRANSIT OF. [TRANSITS OF MERCURY AND VENUS.]

VERANTIN. [MADDER, COLOURING MATTERS OF.]

VERATRIC ACID ($C_{18}H_{10}O_8$). The acid with which veratrine exists combined in Cevadilla. It crystallises in short prisms, which are transparent and colourless, and slightly sour to the taste. It is slightly soluble in cold water, but more soluble in hot, and readily dissolved by alcohol, but not at all by ether.

Neither concentrated nitric nor sulphuric acid decomposes veratric acid, but a mixture of them renders it yellow. When heated to 212° the crystals lose water, and then become of a dull white colour; at a high temperature they melt into a colourless liquid, and sublime without leaving any residue.

The crystals contain one equivalent of water. Veratric acid forms crystallisable salts with the alkalies, which are very soluble in water and alcohol. Their solutions precipitate the salts of lead and silver, and the veratrate of the latter is white, and slightly soluble in alcohol.

VERATRINE ($C_{64}H_{52}N_2O_{16}$), a vegetable alkali prepared from Cevadilla, the seed of the *Veratrum sabadilla*. It was discovered by Meissner in 1818, and obtained by Pelletier and Couerbe in 1819.

Veratrine is a white or greenish-white powder, which has a silky and crystalline appearance under the microscope; it is inodorous, very acrid and poisonous. It is insoluble in water and alkaline solutions; very soluble in alcohol and sparingly so in ether; the solution when evaporated deposits transparent laminæ. The solutions have the alkaline property of restoring the blue colour of reddened litmus.

The salts of veratrine are neutral, and have a slight styptic taste; the hydrochlorate crystallises in short needle-form crystals, which are very soluble in water and alcohol; the sulphate crystallises in quadrilateral prisms; concentrated nitric acid renders veratrine first scarlet and then yellow; concentrated sulphuric acid gives it at first a yellow colour, afterwards a blood-red, and eventually violet.

VERATRUM ALBUM (White Hellebore)—*Medical Properties of.* Of this, two varieties, or distinct species, are officinal: one termed *V. album;* the other *V. album β*, or *Lobelianum*. This last prefers a chalky soil; the plants occur in the meadows of the Swiss Alps, the Pyrenees, the mountains of Austria, and in Siberia. The rhizomas of both kinds are collected indiscriminately. This part occurs single, double, or many-headed, in cylinders, or pyramidal pieces, from two to four inches long, and from three-quarters to two inches thick, rough, wrinkled, of a grayish-black colour externally, but of a yellowish-white within. Some root-fibres, intermingled with slender flexible radicles, adhere to it; and on the upper part are found the scales, or withered remains of former leaves, which from their tunicated appearance have led some writers to describe it as a bulb. This, though incorrect, is useful to remember, as a good discriminative mark between it and other plants confounded with it, which, being *roots* and not *rhizomata*, are devoid of this character. A transverse section presents a large central portion, sometimes termed the medulla; and, according to the age of the specimen, one, two, or more external circles, bounded by the dark-brown epidermis. The rhizoma is nearly devoid of odour, but has an acrid, bitter, burning taste. It is easily powdered, but the person engaged in powdering it should wear a mask, as it excites a heat and eruption of the skin, and any drawn up the nostrils causes violent sneezing and inflammation of the Schneiderian membrane: hence its German name of *nieswurzel*. By time the acridity and activity are diminished, so that old specimens become not only mouldy, but of inferior strength, and should be rejected.

Veratria, called also Sabadillin, is procured from the seeds of *Asagræa officinalis* (Lindley, *Helonias officinalis*, Don) and the *Veratrum Sabadilla*, Retz, as well as probably other seeds of *Melanthaceæ*.

Veratrum viride is used in America as a substitute for *V. album* and also for colchicum. White hellebore is an agent of great and dangerous power. According to the experiments and inquiries of Schabel ('Dissertatio de eff. Veratri albi et Hellebori nigri,' Tübingen, 1817), it is poisonous to all classes of animals, and acts fatally, if in sufficient quantity, by whatever way it is introduced into the system. It appears to have a specific effect on the intestinal canal and nervous system, its effects on these parts being uniform, whether applied directly to them or to remote parts, provided absorption take place. The action is that of a narcotico-acrid poison; but its narcotic effect is less, while its acrimony is greater, than that of black hellebore. It is doubtful whether the plant now spoken of is the *white hellebore* of the ancients. In doses short of any dangerous or violent effect, white hellebore exercises a peculiar action on the secreting organs, the stomach and intestines, and the nervous system. Almost all mucous surfaces, and the glands connected with them, as well as the kidneys, are excited to increased secretion. But when the quantity is more considerable, heat of the mouth, tongue, and throat, with spasmodic constriction of the pharynx, thirst, pains in the stomach and intestines, alternate heats and chills of the whole body, perspirations, anxiety, pain of the head, giddiness, depression of spirits, gloomy expression, and even spasms of the countenance, are experienced: if vomiting fortunately occur early, these symptoms are alleviated. Schabel says that no substance so certainly acts as an emetic; but while tartar emetic or ipecacuanah, or sulphate of zinc, can be had, it ought never to be employed. If the substance be introduced into the rectum, the symptoms are the same, except that the heat of the mouth and pain of the stomach are less. In decidedly poisonous doses its action is that of a violent narcotico-acrid, causing severe vomiting and purging, often bloody stools, tenesmus, burning feeling from the mouth to the rectum, constriction amounting to a sense of strangulation in the throat, with small pulse, faintings, cold sweats, giddiness, blindness, dilated pupils, loss of voice, convulsions, and insensibility, generally terminating in death. The tincture and the alcoholic extract act more powerfully than the watery infusion or extract. A cutaneous eruption sometimes follows the use of white hellebore. Where death does not ensue, palpitation with intermitting pulse, along with dyspeptic and nervous symptoms, remain for some time. The application of white hellebore to wounds or any broken surface, either to destroy vermin or to cure the itch, may produce the above effects; and this result occurs whether it is used in powder, as a wash, or ointment. The popular use of these is therefore to be discouraged. White hellebore is occasionally mistaken for Galanga root, and the seeds for those of cumin: intentional poisoning with it is rare; but from the use of it among soldiers, who have recourse to it from its property of producing palpitation of the heart, and thus simulating disease of that organ, in hopes of obtaining their discharge, violent and indeed fatal effects ensue. It is the active ingredient in some quack medicines for gout or rheumatism, often producing dangerous consequences. It is also the efficient agent in many insect-destroying powders. An efficient antidote is scarcely to be found. Samuel Hahnemann, overrating the antagonising power of coffee, recommends that article; but at best it can only combat the narcotic symptoms, which are not the most formidable. Astringent drinks have also been proposed, but they are not to be relied on. Acid drinks seem more serviceable: hence tamarinds, or cream of tartar may be given, followed by demulcent or oily fluids. Vomiting should be encouraged.

The medicinal employment of white hellebore is not very great in the present day; but when administered with due caution it is of great service in gouty and dyspeptic disorders, where there is torpor of the liver, sluggish bowels, and defective secretion from the kidneys. From its influence on these organs it often proves useful in chronic cutaneous diseases, in which the digestion is always impaired. It is likewise used as a sternutatory, largely diluted with some starchy powder. Externally, veratria is employed to relieve nervous pains; but its use requires the greatest caution.

VERB. [Language.]

VERDERER. [Forest Laws; Woods and Forests.]

VERDIC ACID, an acid discovered by Runge, and so named from its property of becoming green by exposure to the air. It is obtained from several of the *Umbelliferæ*, *Plantagineæ*, &c., but chiefly from the root of the *Scabiosa succisa*. When combined with excess of base, it becomes green in the air, owing to the absorption of oxygen; Berzelius, therefore, proposes to call the colourless the *verdous*, and the coloured the *verdic* acid. The former is obtained by digesting the dried and powdered root of the scabiosa in alcohol, from which on the addition of ether white flakes are thrown down; to these, dissolved in water, acetate of lead is added, and the precipitate thrown down is decomposed by hydrosulphuric acid. By evaporating the filtered liquor the acid is obtained in the state of a brittle yellow mass, which reddens litmus and does not alter in the air. When it is saturated with an alkali, ammonia for example, and exposed to the air, it absorbs oxygen and becomes gradually green. The acids then precipitate it in the form of a reddish-brown powder, which is verdic acid: this redissolves and becomes green with the alkalies. The earthy or metallic *verdites* are yellow, while the *verdates* of the same bases are green. Runge states that he found by analysis that verdic acid contains one equivalent of oxygen more than the verdous acid.

VERDICT. [Jury.]

VERDIGRIS. [Acetate; *Diacetate of Copper.*]

VERDITER. [Copper; *Acetate of Copper.*]

VERDOUS ACID. [Verdic Acid.]

VERMICELLI, a dried paste, manufactured chiefly in Italy in the form of smooth round strings. The name has been given to it on account of its worm-like appearance, *vermicelli* in Italian signifying little worms. *Maccaroni*, which the Italians spell *maccheroni* or *maccherone* (a word of doubtful etymology), is manufactured of the same kind of paste as vermicelli, and in a similar manner; but it is rather larger in diameter, and is hollow like the tube of a tobacco-pipe. *Fedelini* is a kind still smaller than vermicelli.

The paste is made of wheat stripped of the husk, and ground roughly into a sort of grit. The kind of wheat preferred by the Italians is a small hard-grained species which they now cultivate on purpose, but which they formerly imported from the coasts of the Black Sea—*grano di Mar Nero*. The ground wheat is mixed with clear soft water, and made into a paste by kneading it on a large block with a wooden lever ten or twelve feet long. The short end of the lever is made sufficiently heavy to lift the long end, on which one or two men or boys get astride, and alternately sitting down and springing up, work the paste for a long time. The toughness and elasticity of the paste result from this long and powerful process of kneading. The paste is next forced by strong pressure through round holes in the bottom of a cylinder; but, to form maccaroni, a wire extends from a bridge in the upper part of the cylinder through the centre of each of the largest holes, and the paste, being forced through each hole around the wire, is consequently hollow. The strings, several feet in length, whether of maccaroni, vermicelli, or fedelini, having been thoroughly dried, are ready for use.

The Italians manufacture the paste into many other forms; into thin flat strips like ribbons, into thin sheets like paper, into round balls, and into beans and peas. The Neapolitans, who use great quantities of maccaroni as their favourite food, use nothing but the pure paste of wheat and water, but the Genoese mix saffron with it, which gives it a yellow tinge. The French, who also manufacture a good deal of it, frequently season the paste with various condiments.

VERMILION. [COLOURING MATTERS; MERCURY.]

VERNAL, VERNAL EQUINOX. The word vernal is the adjective derived from *ver*, the spring; and the vernal equinox is that point of the equator which the sun crosses when it passes into the hemisphere of the observer, and when his days begin to be longer than the nights. Consequently that point of the ecliptic which is called the first point of Aries is the vernal equinox to those in the northern hemisphere, while the first point of Libra is the same to those in the southern. If there were any decidedly astronomical nations south of the equator, some confusion might perhaps have arisen; but as all the science will be carried from the north, it is probable that the terms and modes of measurement peculiar to the north will be universally retained.

VERNIER. We shall give under this head a short account of the different methods employed to measure the parts of the divisions of astronomical and geodesical instruments. This and the article GRADUATION may be considered as a sort of introduction as well as supplement to the description of each particular instrument. It is necessarily both meagre and imperfect, but the references will point out the principal authorities to be consulted. We shall conclude with a brief account of the vernier in its simplest form.

We are not aware that the Greeks or their successors the Arabs had any contrivance for subdivision. They seem to have simply divided their circles as accurately as possible, and into small convenient portions. Ptolemy's catalogue does not profess to distinguish less quantities than 10′; or rather, the parts of degrees are marked fractionally with no larger denominator than 6. Ulug Beigh used instruments of greater dimensions, and seems from his catalogue to have noted minutes. At the revival of astronomy in Europe the instruments were very rude, and the simple division, aided by estimation, was probably considered sufficiently accurate without any artificial contrivance.

Peter Nonius, in the third proposition of his treatise 'De Crepusculis Olyssipone,' 1542, proposed the following graduation for astronomical instruments:—Forty-five concentric circles are to be inscribed on the limb, and separated into quadrants by diameters intersecting at right angles. The quadrants are then to be sub-divided as follows:—the outermost into 90 equal parts, each of which consequently equals 1°; the next into 89, that following into 88, and so on to the innermost, which is to be divided into 46 equal parts. Each circumference is marked at a convenient place with the number of its subdivisions. The fiducial edge of the bar carrying the sights passes, when produced, through the centre, and the author assumes that whatever be the direction of the line of sight, the fiducial edge will cut some one of these circles at a division without sensible error. The corresponding angle in degrees, minutes, seconds, &c., is readily computed from the number of parts intercepted and the order of the circle. Thus if the exact coincidence takes place at division 29 of that quadrantal arc which is divided into 77 parts, the corresponding arc in degrees is $\frac{29}{77}$ of 90°, which is, when reduced to its ordinary denomination, 33° 53′ 46″ very nearly.

Tycho applied the graduation of Nonius, or a modification of it, to some of his earier instruments, but "quia hæc subtilitas, cum ad praxim deventum est, plus habeat laboris quam fructus, neque id in recessu præstet, quod primâ fronte pollicetur," he abandoned it, and adopted the method of *transversals*, which is well known to most of our readers as the diagonal scale in the case of drawing-instruments. This Hooke says ('Animadversions,' &c.) "was first made use of in England by the most skilful mathematician Richard Cantzler." Tycho describes this mode of subdivision in the supplement to his 'Mechanica,' Norimbergæ, 1602. Two concentric circles are drawn upon the limb at about $\frac{1}{40}$ of the radius from each other, and divided into equal parts of 10′. The space from the zero of the inner circle to the 10′ division of the outer circle is divided into 10 equal parts by 9 fine dots; and in like manner the space between the 10′ of the outer circle and the 20′ of the inner, and so on. These rows of points form a sharp zigzag with the angles in the two circles. The index, which may be either a fiducial edge or a fine hair, will pass over or near one of these dots in every position, and the angle to be read off is the number of degrees and tens of minutes which is taken from the circles, inner or outer, + the number of minutes and parts of a minute (the latter by estimation) reckoned by counting the points from the preceding angle. Tycho became acquainted with this division by diagonals as applied to straight lines when a student at Leipzig, and in the place above referred to he proves that this subdivision, though not theoretically exact when applied to curved lines, was yet sufficiently true for his purpose. Instead of dots, other astronomers struck nine concentric circles at equal distances, and then drew straight lines where Tycho placed his dots.

In the year 1631 Pierre Vernier, Capitaine et Chastellain pour sa Majesté au Chasteau Dornans, &c., published at Bruxelles 'La Construction, l'Usage, et les Proprietez du Quadrant nouveau de Mathematique,' which he dedicated to the Princess Isabella. He supposes a quadrant divided into half-degrees on the limb, the surface of which rises above the plane of the instrument (this he calls the base), and a moveable plate of the form and figure of a sector (and so named by him), which is concentric with and exactly fitted within the limb, the surfaces of the two forming one plane. An arc of 15° 30′ is then set off on the sector, which is subdivided into thirty equal parts. He directs two lines of sight to be fixed on the extreme radii of the sector, which therefore include an angle of 15° 30′, and orders the division to degrees and half-degrees to be numbered one way on the limb from left to right, and the divisions of the sector to be numbered up to 30′ from right to left. Suppose the line of sight towards the zero end of the quadrant to be directed to any object:—If the division 30′ on the sector (we will now call this the *vernier*) which answers to the line of sight, seems to be a continuation of a division of the quadrant, the angle read off will be that degree or half-degree of the quadrant, and the 0′ of the vernier will exactly correspond to another division of the quadrant. No other division of the vernier will so correspond if the division be exact. Now it will easily be seen that as the arc of 15° 30′ is divided on the vernier into 30 equal parts, each part is equal to 31′; and therefore that when 0′ is placed opposite a division of the quadrant, the division 1′ of the vernier overshoots the next division of the quadrant 1′ in the direction of the vernier, and contrary to the numbering of the limb. If the line of sight were pushed forward 1′, the vernier division of 1′ would therefore agree with a division in the quadrant, and so on; so that in fact, whatever be the position of the line of sight, the true angle is to be read off, first as to degrees and half-degrees from the quadrant, and then for the minutes from the vernier.*

In 1643 Benedictus Hedræus published at Leyden his 'Nova et Accurata Astrolabii Geometrici, nec non Quadrantis Astronomici Structura,' dedicated to his sovereign, Queen Christina of Sweden. In his preface he objects to the inaccuracy of Tycho's method of transversals, and gives himself a correct construction, namely, by describing a circular arc through 10′ of the outer division, 0′ of the inner division and the centre of the quadrant, and dividing that portion which is included between the inner and outer circles into ten parts, when the subdivision will be true. Hedræus has adopted the vernier, but without naming the inventor: his astrolabe and quadrant are well contrived.

Hevelius applied to his instruments the transversal division of Tycho as well as the vernier. He seems to claim the invention of the tangent-screw for giving a slow motion to his line of sight, and dwells at great length on the subdivision of the larger divisions by the revolution and parts of the tangent-screw. ('Machina Cœlestis,' Pars Prior, cap. xv. Gedani, 1673.) So far as we can judge from his assertions and description, he arrived at great excellence in this part of mechanical construction, which however his unaccountable rejection of telescopic sights rendered of little value.

The next year after the appearance of Hevelius's book, Hooke published at London his 'Animadversions on the first part of the Machina Cœlestis of the honourable, learned, and deservedly famous astronomer Johannes Hevelius,' a tract distinguished by its acuteness and originality. It is remarkable that he did not see the merit of Vernier's invention,† nor, as it would seem, of Hevelius's application of the revolutions of the tangent-screw to measuring very minute quantities. He suggests a very elegant application of the diagonal scale, with rules for its accurate division when applied to circular arcs, but recommends racking the outer edge of the quadrant and measuring the angle by the revolutions and parts of the screw which carries the telescope by working in the racked limb.

Hooke's unlucky idea was carried into execution in Flamsteed's sextant, and turned out so ill that the diagonal division was applied as an after-thought. See his prolegomena ('Historia Cœlestis,' vol. iii. p. 106, and Baily's Flamsteed.) Hooke's advice was afterwards followed in making a quadrant for the Greenwich Observatory, which was also found to be useless. In the mural arc which Flamsteed erected at his own expense and under his own direction, he drew diagonals after having divided the inner and outer arcs to 5′. The subdivision was performed by dividing the fiducial edge of the index, not into five equal parts but into such parts as would give the minutes exactly, and each of these was divided into six equal parts; so that the instrument read off to 10″, and by estimation to 5″. The outer edge was also racked after Hooke's method, but rather, we think, as a check against erroneous reading, than as a means for exact measurement.

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* Vernier's tract is very scarce, and the injustice of those writers who persisted in giving the name of Nonius to his invention has induced us to enter into a more particular exposition of both principles. The second line of sight is merely to enable the observer to extend the angle to 90° without carrying the sector beyond the quadrant. He gives a very prolix account of the graduation proper for quadrants and astrolabes of different sizes, and how angles exceeding 90° are to be measured, but of this no further notice is required here.

† Hooke conjectures that Tycho had invented Vernier's contrivance and rejected it, but without any probability. Tycho's words and figure refer clearly to some change of Nonius's divisors.

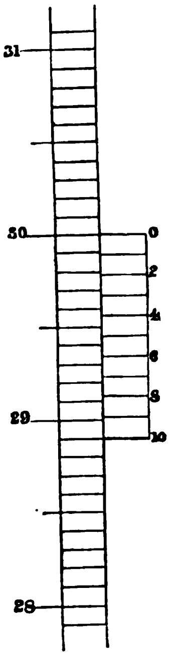
Römer proceeded in a totally different manner. The limb of the circle was divided to 10′, and a magnified image of each division was formed in the focus of a microscope, so as exactly to fill the space between eleven threads at equal intervals. Thus the arc was read off to minutes by the threads and the seconds estimated, which they easily might be to 5″, according to Horrebow.

The vernier appears to have come into general use after Flamsteed's time, and in the larger quadrants there were usually two sets of divisions, one into 90° and the other into 96 parts, each with their peculiar vernier: the approximate divisions were brought into exact coincidence and the quantity measured by the revolutions and parts of the tangent-screw, after Hevelius's method. Such were the mural quadrants at Greenwich and elsewhere, erected by Bird, Ramsden, &c., in the last century; and the portable astronomical quadrant had the same or similar contrivances for subdivision. In the sector employed in the French survey, and described in 'La Méridienne de Paris verifiée,' Paris, 1744, the arc was divided by fine points to every 10′. In making the observation the plumb line was first brought directly over one of these dots, and the star afterwards bisected by a micrometer-screw carrying a wire in the focus of the telescope. The degrees and tens of minutes being read off on the limb, the revolutions and parts of the screw furnished the remaining minutes and seconds. This method of subdivision was applied by La Caille to the sextant with which he observed at the Cape of Good Hope and at Paris. The invention is due to the Chevalier de Louville, whose memoir is to be found in the 'Mémoires de l'Académie' for 1714.

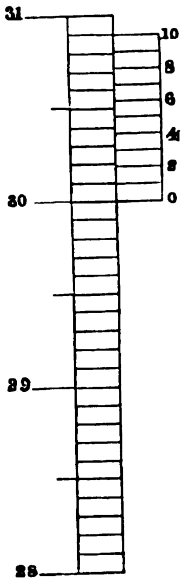
We have already mentioned Römer's optical method of subdivision. The invention of the micrometer-microscope, in which the divisions are first magnified and the intervals measured by the revolutions and parts of a screw carrying a wire or cross-wires in the focus of the object-glass of the microscope, is due to the Duc de Chaulnes, whose account was published in 1768: 'Description d'un Microscope et de differents Micromêtres,' &c. The reader will find some account of the construction and verification of the micrometer-microscope in the article CIRCLE.

We will now briefly explain the principle of the vernier in its simplest form. If that be well understood, the reader will have little difficulty in making out the value of the divisions in any instrument to which the vernier is applied, though he may require considerable practice before he is able to read off well and quickly.

No. 1.



No. 2.



Number 1 is the figure of a vernier for measuring hundredths of an inch, such as is usually applied to common barometers. The scale is on the left hand, on which the inches and tenths are marked. The portion on the right hand, which can be slipped up or down, remaining always in contact with the scale, is the vernier. It is merely a length of 11 parts of the principal scale divided into 10 equal parts. Each of these parts, therefore, equals $\frac{11}{100}$ of an inch, or ·11 and the difference between a part of the scale and a part of the vernier is ·01 inch. In the figure the zero of the vernier is made to coincide, that is, to form one continued line with the division 30 on the scale, and consequently 10 on the vernier also coincides with 28·9 on the scale. Division 1 on the vernier is, from what we have said, ·11 inch below the zero of vernier, while the next lower division on the scale is only ·10 below it: hence the vernier division 1 is ·01 inch below the division 29·9 on the scale. For the same reason division 2 on the scale is twice as much, or ·02 below 29·8 on the scale, and so on, the divisions on the vernier overlapping those on the scale until 10 on the vernier stretches over to exact coincidence with 28·9 on the scale. Now suppose the vernier to be raised ·01 inch, it is evident that division 1 of vernier will coincide with 29·9 on the scale. If the vernier were raised ·02 inch, the vernier division 2 would coincide with 29·8 on scale; and so on; so that in order to read off the hundredths of an inch which the vernier zero advances beyond any tenth in the scale, we have merely to see what vernier division comes nearest to a division of the scale, and set that down for the hundredth required.

This is the form which was given to the vernier by its inventor, in which the parts of the vernier are larger than those of the scale, and in which the numbering of the parts of the vernier runs contrary to the numbering of the scale. But if, as in No. 2, the vernier has the length of nine divisions of the scale, and this is divided into ten equal parts, each part will be equal to ·09 inch, while the divisions of the scale are equal to ·1 inch. The vernier in this form is to be numbered *forwards*, as well as the scale. It is clear that raising the vernier ·01 will bring the division 1 of the vernier into coincidence; and so on, exactly as before; and, therefore that the inches and tenths being read from the scale, the hundredths are to be taken from the vernier. The reading both scales forward is some advantage in favour of the latter mode, while the size of the vernier divisions is larger, and consequently clearer, in the first. There might perhaps be some advantage in particular cases in uniting both verniers, as the reading would be made on two divisions and by two sets of independent subdivisions, but we do not remember to have seen this in actual use.

In modern astronomical and geodesical instruments the vernier usually reads forward. Sometimes, for greater compactness, the zero is placed in the middle of the vernier, and the graduation, after running on to the end of the vernier, is continued from the other end of the scale to the middle, and reads both backwards and forwards. There is a great liability to confusion in these verniers, which can only be avoided, at first, by guessing the value of the subdivision before reading the vernier. We prefer simple verniers, reading always forward with the zero at one end.

The ordinary subdivision in English instruments is to minutes, half-minutes, twenty seconds, and ten seconds. Thus if the circle be divided to 30′, and the vernier taken equal to 29 half-degrees, and then divided into 30, each part of the vernier will equal $\frac{29}{30}$ of 30′ or 29′, and the difference between a part of the circle and a part of the vernier be 1′. If the circle be divided to every 10′, and the vernier taken equal to 59 of these parts (=9° 50′), and divided to 60, each part of the vernier will be $\frac{59}{60}$ of 10′, that is, will be equal to 590″ or 9′ 50″, and the difference between a part of the circle and a part of the vernier be 10″. This division is legible in circles of 8 inches diameter. In circles of 18 inches diameter we should still adopt the same division, as it is easy to estimate the difference, and less fatiguing to read an open division than a crowded one.

The continental artists generally make one circle turn closely, but freely, within another, and nearly in the same plane, as we have seen was directed by Vernier. The reading is much more pleasant and exact in this way. Troughton objected to it, that if a particle of dust should get between the circles it would necessarily grind and tear the edges of the circles, leaving a muddy and ragged ditch between them. We do not know whether this objection is confirmed by experience. The English artists generally place their verniers on thin plates which move upon the divided circles. There is some chance of rubbing, and a certainty of wearing, if the verniers press on the circle; and if they stand off from it they are awkward to read, with a chance of considerable error from parallax. The subdivision by the vernier seems to be preferred by the German artists in general to that by micrometer microscopes, which are in England universally applied to large meridian circles, and indeed to all considerable instruments where the fixing of the microscopes is not subjected to a varying effect of gravity. On the side of the verniers may be pleaded cheapness, and freedom from changes, such as those which the scale of a microscope suffers when the distance between the limb and the object-glass of the microscope, or the body of the microscope itself, from expansion or other cause, is altered. On the other hand, the micrometer microscope certainly admits greater magnifying power, keeps the observer away from the instrument, can be fixed with greater firmness, and remains more steady. It is not easy to fix a vernier firmly without running the risk of affecting the motion of the circle. On the whole we prefer the micrometer microscope, although it must be admitted that the perfection which the continental artists give to the centering of their circles and verniers may well cause a difference of opinion. For small instruments, and those which, like the declination circle of an equatorial, are placed under different strains in different positions, the vernier is indispensable.

There is difficulty very often in getting the proper light on the divisions. It is desirable that those of the vernier as well as those of the limb should appear sharp and black, and the divisions before and after that which is nearest to coincidence should be scrutinised in order to estimate the decimal or fraction which is wanted for perfect coincidence. A more perfect setting will generally be obtained by making the divisions before and after the coincident division equally discordant, than by attempting to get a perfect coincidence. The observer should be careful to view the divisions directly, and in the centre of the magnifier, or he will have an error arising from parallax which may be considerable.

The truth of a vernier in one respect, that of its embracing a proper portion of the limb, may be tried in different parts of the limb. If the circle be very excentric this may give a little trouble at first, and be confounded with bad division. In ordinary cases, however, if there are opposite verniers, and their extreme divisions sometimes overlap and sometimes fall short of the corresponding portion of the limb, the mean will be true although the excentricity is sensible. The number of verniers may be either two, three, or four, at equal distances. Two are absolutely necessary to get rid of excentricity, and three or four will also nullify any error, original or superinduced, which gives the circle an elliptic form. But it is not easy in all cases to apply these readings conveniently, and the fatigue of many readings is scarcely recompensed by a little superior accuracy, at least in well-made and well-divided instruments which are carefully handled.

VERSED SINE. [TRIGONOMETRY.]

VERSION. The word version, or translation, is used to express the transferring of some written composition from one language into another. Like many other terms, translation cannot be briefly defined: the notion of translation must be attained by a consideration of all the conditions of translation; and the right understanding of its nature involves a part of the general theory of language.

If two languages corresponded perfectly; if every term in the one language had its equivalent in the other; and if the forms of speech in the two languages were also perfect equivalents, the difficulty of translation would not be great. It would only be necessary to discover the equivalent terms and the equivalent forms of speech in the two languages, and translation would be effected by mere substitution. In this supposed case, as the terms and the forms of expression would be perfectly equivalent, a person who should read the translation would understand it exactly as a person would understand the original; for the supposition of the two languages being perfect equivalents involves the supposition of the objects of thought and the mode in which their relations to one another are viewed being the same for the people who use the two languages. Now no two languages have this perfect equivalence of terms and forms of speech, and therefore a perfect translation cannot be made.

The general distribution of words into notional and relational words is explained in the article NOTION. In no two languages are all the notional words perfectly equivalent. Such words as express many of the ordinary objects of sense, as sun, moon, man, woman, are perfect equivalents; but all the words which express objects of sense in one language have not their equivalents in another. Various nations have various articles of dress, various utensils, implements, and ornaments which are peculiar to them, and consequently have not their equivalents in another language. If such terms are rendered by some other term in the language into which the translation is made, the translation will not convey the exact notion of the original, though it may come near enough for many purposes. In some cases the difference is immaterial, as may be shown by instances; in others the difference is material. The Latin words "domus" and "navis" may be respectively rendered by the English "house" and "ship," though Roman houses and ships differ considerably from English houses and ships. But if the word "domus" is merely used to signify the general notion of a dwelling for man, as for example, when one wishes to say that a "man was killed in a house and not in the street," the precise difference between Roman houses and English is immaterial, for house in such case is used in its most general sense. But if in the original Latin passage anything turned on the difference between "domus" and "villa" as opposed to one another, then, unless the English language possessed two words which should stand in the same opposition to one another as "domus" and "villa," a translation could not be made simply by equivalent terms: it must be effected in some other way. Material objects then, for which there may be equivalents in two languages when the object is used in its most general sense, may not have equivalents in the two languages when used in this special sense. Thus the Latin words "patera," "urna," "lanx," are words which express the general notion of a thing that is used to contain other things; but as they are also used to indicate a particular kind of containing vessel, there can be no translation of such terms unless we have both the things and the name for them. It appears then that, even in the case of such ordinary things as domestic utensils, a translator will often be at a loss to find a word equivalent to the original word; and he must either find a word which comes the nearest to it, or he must adopt the original word. In the one case he will not convey an exact notion to the reader, and he may convey a very erroneous notion; in the other he will convey none at all, unless the reader happens to know the thing intended by the term in the original language. The context may often help to the right understanding of a term, but that is not the matter at present under consideration.

The terms which denote the political and religious institutions or usages of a country often present still greater difficulty. The Roman terms "Ædilis," "Consul," "Comitia," "Tribus," "Judex," "Pontifex," "Augur," cannot be rendered into our language by any equivalent terms. In these and many similar instances it has become usual to adopt the original term, with the termination sometimes slightly altered, and the reader of such translations is supposed either to know what these terms mean, or to have books which will explain them. This is in fact the only practicable mode of translating such terms, and such translation is not liable to more objection than a book in one's own language which contains numerous technical terms, the explanation of which is not given in the book, and cannot be got from the context, but must be sought for in a dictionary or work of reference.

If the original language has been more cultivated than the language into which the translation is made, the translator will find that he is ill provided with terms equivalent to those of the original. Foreign works on jurisprudence or philosophy, when translated into English, present this difficulty, which can only be overcome by adopting the technical terms of the original language. If the translator were to attempt to make names which should correspond to the original terms, he would not be so likely to succeed in getting them adopted as by transferring the original terms into his translation.

That part of translation then which consists simply in finding equivalent notional terms is limited. It depends on the character of the two languages, the original and that of the translation, how far equivalent terms can be found. In all matters which characterise the usages of a people, it is impossible to find equivalents in two languages, for by the term character is here meant something which each has and the other has not. As to all terms which are the expression of universal notions, such as are in a great degree independent of the character of a people, those languages which have been cultivated to an equal degree do possess terms which are sufficiently equivalent. But even here there is often a very great difficulty in ascertaining the equivalent terms, as any one may satisfy himself by attempting to translate into English such a work as Cicero's treatise on the Orator, or some parts of Tacitus.

Perhaps it is often easier to translate from one language into another when the two languages have no historical connection, than when they are related as original and derived languages, or as languages which have interchanged terms, or where the exchange has been all on one side; for it often happens that words which are transferred from one language into another retain nearly the original form, and yet have either been adopted in a different sense from the original sense, or have in course of time acquired such different meaning. It would be easy to find numerous examples of such change of meaning in words that have been introduced into the English either directly from the Latin or through the medium of other languages.

The union of notional words into connected speech or language is effected by the words of relation, which are either appendages added to words, or separate small words, or both; and it is also effected by the order of the words. Now the words of relation and the order of words differ considerably in most languages, and hence arises a great difficulty in translation; for language consists not of single words, no more than a ship consists of trees: in the case of language and a ship, words and timber are materials, but materials without form have no significance. Yet in everything the nature of the material is an element in the capacity for receiving form; and in language the possession or absence of case-endings, and of suffixes which show the modifications of words, called mode and tense, materially influences the capacity of the language for expressing a given idea with perspicuity, brevity, and force: it also materially affects the possible order of the words. Those languages which possess case-endings and verbal terminations in abundance can vary the order of the words in a great number of ways, so as to place particular words in those positions where they shall be most effective. A language like the English, which, in its present form, has few suffixes, is much more limited in this power than the German, the Greek, and the Latin. Languages also differ greatly in the number of small words (relational words) which are adapted to express the relation of notional terms to one another. Some of the more delicate colours which are thus expressed in one language are absolutely incapable of being expressed in another by any corresponding relational words, and sometimes they cannot be expressed by any combination of words.

It will now not be difficult to ascertain in a general way what can be effected in a translation, and what ought to be attempted. Some people have had a notion that a translation should be literal, or near to the original, by which it is meant that every word of the original should have its equivalent in the translation, or nearly so. There is no objection to this, so far as it can be done consistently with the proper idioms of the translator's language; yet such a translation is not commendable because it is literal, but because it is true. The idiom of the translation must not be corrupted by an imitation of the idiom of the original. If what is called a literal version is a sufficient version of the meaning, and if it is also expressed in a true idiom, the translation is good; but its literal character is a mere accident. It will depend both on the character of the two languages and on the character of the original work how far the version shall in its form correspond to the original. Simple narrative is generally easily rendered from one language into another without varying much from the form of the original. Works which have more of an artistic character present greater difficulties, whether they are historical, critical, or poetical. Poetry presents the greatest difficulties, because, in addition to the general difficulty of transferring the meaning of one language into another, there is the difficulty of reproducing the rhythmical form of the original, and this is sometimes impossible. Horace succeeded in introducing the Greek lyric metres into the Latin language in his translations or imitations; but Horace was a master of his art, and he had a language which was sufficiently near to his original. The translations of Voss from the Greek and Latin poets have the advantage of being in a language which, from its copiousness, its grammatical forms, and its capacity of combining words, renders such an undertaking practicable in skilful hands. The English language has copiousness and energy, but less flexibility than the German, and the imitation of the rhythmical forms of other languages is sometimes impossible in an English version; and without this imitation the translation of poetry is incomplete, for the metrical form is a part of poetry. It is indeed often as easy to express in a prose translation the ideas of poetry as those of prose composition, for the essential qualities of poetry are not destroyed by reducing it from its metrical into a prosaic form. In this form it may still fill the mind with the images of the original, but it will not equally affect the passions; for the passions are most vehemently moved by direct sensuous impressions, and the sensuous character of poetry is its metrical form. All attempts therefore at poetical translation from one language into another can only be partially successful unless the character of the two languages admits of a perfect metrical imitation in the translation.

A translator should show his judgment by the choice of his subject as well as by his manner of handling it. He will not choose what is incapable of being rendered adequately. He will not attempt to fashion his form of expression to that of the original by doing violence to his own idiom. He will neither servilely follow the division of sentences nor the forms of expression. He will labour to penetrate through the author's language to his meaning, and he will then strive to express that meaning in his own language. He must rigidly scrutinise the result of his labour, to see if it conveys the same meaning as the original, and neither more nor less. When this is accomplished, his translation will be sufficient, though it may not be perfect. It will be all that a translation often can be—a sufficient copy of the original.

But there may be something wanting. Every writer has peculiarities which constitute his style. One writer is sententious, compressed, and energetic, but perhaps obscure; another is diffuse, flowing, and redundant, but fills the ear more than the mind; a third may be perspicuous and simple, but withal feeble. Now a translator who should so far mistake his original as to give a diffuse version of a sententious writer, or to express any original in a form which should be altogether unlike it, would show that he had ill appreciated the writer's character, and this would not be the only blunder that we might expect from him. A version of a prose writer which should possess a general character altogether unlike the original, would as little merit the name of a translation as a dull prosy version of the 'Iliad' would deserve the name. To fix a true medium between a close imitation of the style of the original and a wide departure from it, belongs to that department of the business of translation in which taste is concerned. It is something wherein precise rules can never be laid down, and yet the best critics will not disagree in their judgment. It is a gross error which we see in some attempts to translate Tacitus, to reproduce the original with all its obscurity and brevity: it is a grosser blunder to weaken his sententious energy by a profusion of words, many of which, being impertinent and idle, only form a stronger contrast with those of the original, which have been selected and arranged with studious care.

Like portrait-painting, translation has only one rule, and that not a rule which shows us how to act, but only prescribes a certain end. Make your copy like the original: let no man mistake it. Many copies may be made, and all may be pronounced to be likenesses. Compare the likenesses with one another, and you will find one which shall be more like than the rest. Ask the master how he made it: he will say that he copied the original; but how he did it you cannot understand, nor can he say.

VERTEX, a name given to any remarkable or principal point, particularly when that point is considered as the top or summit of a figure. Thus we have the three vertices of a triangle, the vertex of a cone or pyramid, &c.

VERTICAL. The zenith being considered as a vertex, which in fact it is, when the word vertex means summit, a vertical plane is one which passes through the line drawn from the spectator to his zenith; a vertical plane therefore merely means one which is perpendicular to the horizon, and a vertical line has the same meaning.

VERTICAL, ANGLE OF THE. A name given to the angle made by the diameter through any point of the earth, supposed a spheroid, with the direction of gravity at that point, or the perpendicular to the tangent plane.

VERTIDINE. A base, not yet analysed, contained in shale tar.

VERTIGO, or giddiness, is a peculiar sensation depending probably on some disturbance of the circulation in the brain. It need not be described, for whoever has not felt it may do so at once by turning round a few times rapidly. The nature of the change produced in the brain by the numerous causes of giddiness is altogether unknown; probably the sensation may be the result of several different conditions, for it ensues alike when the pressure of the blood upon the brain is diminished by bleeding, and when it is increased in plethora, or what is called determination of blood to the head: it is a sign too as well of deficiency of food as of repletion; and of the various continued movements by which the steady flow of blood through the brain may be disturbed, though the rotatory motion is the most general cause of giddiness, yet the movement of the head backwards and forwards or from side to side will produce it as effectually, and the vertical movement, such as is endured in the pitching of a ship, more certainly still. At present therefore it must be concluded that whatever disturbs the movement or the pressure of the blood within the brain may produce giddiness; and that in some cases it occurs without any cause of this kind, as a sympathetic or purely subjective sensation, dependant on the state of the substance of the brain itself.

As a sign of disease vertigo by itself indicates very little. No judgment can be formed from it except by taking it in connection with the other characters of the affection of which it is a part, and these will generally be sufficiently indicative. Its most common cause is some disturbance of the digestive organs, and it may be safely treated in that view, except in those who are prone to apoplexy or other cerebral disease, in whom it must be always regarded with fear.

VESICANTS. [Blisters.]

VESTA. [Asteroids.]

VESTA (Ἑστία or Ἱστίη, Hestia, or Histiē), one of the great divinities of the ancients, and common both in name and mode of worship to the Greeks and Romans. According to Hesiod, she was the first-born daughter of Kronos and Rhea, and sister of Zeus, and the Romans therefore made her the daughter of Saturn and Ops. She was a maiden divinity, and was said to have vowed eternal virginity by the head of Zeus.

Vesta was the goddess of the hearth; and as the hearth was with the ancients the centre of the family, where the members met, conversed, and took their meals, Vesta was regarded as the goddess of domestic union and happiness. Strangers and friends were hospitably received at the hearth; suppliants sought safety and protection there; and there the members of a family swore fidelity to one another. The fire burning on the domestic hearth, the symbol of domestic union, was also regarded as the symbol of Vesta herself. As according to the notions of the ancients the state was formed on the model of a single family, each political community, city, or state had its public hearth or altar of Vesta, on which a perpetual fire was kept burning. At Athens the public hearth of Vesta was in the Prytaneum, and here the guests of the state and foreign ambassadors were received and hospitably treated. The public hearth was to the members of a civil community what the domestic hearth was to the members of a family; and when a state sent out colonists, they took from the public hearth of the metropolis the fire which was henceforth to blaze on the public hearth of the colony. Larger communities than a mere town or city had likewise their public hearth and centre of union. Thus the common hearth of the Greeks was at Delphi, and that of the Latins at Lanuvium, the metropolis of the Latins. Later speculators and mystics extended this idea even farther, and spoke of a central fire or a common hearth of the earth and the universe. Vesta, as the protectress of the family, is intimately connected with the Penates, and she herself is sometimes called a Penas or Dea Penetralis. Her connection with the house led some ancients even to ascribe to her the art of building houses.

In Greece, Vesta had very few temples, because every house and every prytaneum was regarded as her sanctuary, and because she had her share in all the sacrifices which were offered to other gods; and at all sacrificial feasts the first and last libations were offered to Vesta. But at Hermione in Argolis she had a special temple, though, like her temple at Rome, it contained no image of the goddess. The sacrifices offered on her altar consisted of seeds, fruit, libations of water, oil, or wine, and of young cows.

Æneas was believed to have brought the sacred fire of Vesta together with the Penates and the Palladium from Troy to Italy; and at Rome the worship of Vesta was said to have been introduced by Romulus or Numa. Her worship at Rome was of much greater importance than in Greece. Her temple, which was of a round form, stood in the forum near that of the Penates; it was open during the day and closed by night. According to Ovid's description, its walls consisted in the earliest times of wicker-work, and the roof of reeds. The temple contained the altar of the goddess with her sacred fire, the extinction of which was regarded as an omen of the greatest calamity to the republic, and priestesses (at Athens and at Delphi widows, and at Rome virgins) were appointed to keep the fire alive. With the exception of the Pontifex Maximus, no male being was allowed to enter the temple of Vesta; and hence we never hear of the senate meeting in it as in other temples. The Roman prætors, consuls, and dictators, on entering upon their offices, had to offer sacrifices to the Penates and to Vesta at Lanuvium. Representations of Vesta in works of art were not frequent in antiquity, as she was worshipped in the form of the sacred fire burning on the hearth. But some are mentioned by Pausanias and Pliny, and she was represented in the grave and dignified attitude and expression of a majestic and pure maiden, with the attire and veil of a matron, and holding in her hand a sceptre or a lamp.

(Hartung, *Die Religion der Römer*, ii., p. 111, &c.; R. H. Klausen, *Æneas und die Penaten*, ii., p. 624, &c.; Müller, *Arch. der Kunst*, § 382; Hirt, *Mytholog. Bilderbuch*, i., p. 70.)

VESTAL (" Virgo vestalis," ἑστιάς), a priestess of the Roman deity Vesta. The number of these priestesses, according to the regulations of King Numa, was four, two for each of the ancient tribes. Servius Tullius, or, according to others, Tarquinius Priscus, added two more, to represent the third tribe, or Luceres. In the earliest times they were chosen by the kings, but afterwards by the Pontifex Maximus, who had the especial superintendence of everything connected with the worship of Vesta. At first the selection seems to have been left to his discretion, but subsequently, whenever there was a vacancy in the sisterhood, he drew by lot one out of twenty select virgins in the assembly (in concione). It might happen that a parent offered his daughter, though this seems to have been the case very rarely. After the lot was drawn, the Pontifex took hold of the virgin, as if she were a prisoner, and having pronounced a certain solemn formula, he conducted her to the atrium of Vesta. Parents could only oppose their daughter being thus taken from them and devoted to the service of the goddess, in three cases: first, if one of her sisters was already a vestal; secondly, if the parents had no more than three children; and, thirdly, if the father held one of certain high priestly offices. In these cases parents were exempt from the obligation of allowing their daughter to become a priestess of Vesta. The conditions, on the other hand, on which alone a virgin could be made a vestal were—1, that her father was not carrying on a disreputable occupation; 2, that her parents were free and free-born, and settled in Italy; 3, that both her parents were alive; and, 4, that she was neither younger than six nor older than ten years. From the moment that a vestal virgin was chosen and taken to the atrium of Vesta, she was emancipated from her father's power; she required no patron in any court of justice, and had the right to dispose of her property by testament; and if she died without having made a will, her property fell to the republic. A vestal virgin, if once appointed, was obliged to serve the goddess for thirty years. The first ten years were a period of noviciate, during which they received instruction respecting the various duties that they had to perform. Then followed ten years during which they were allowed to perform all the functions of their office; and during the last ten years they instructed those who were going through their apprenticeship. After the expiration of the thirty years they might, if they liked, unconsecrate (exaugurare) themselves, and might marry. This, however, happened very seldom: it was considered unlucky for vestals to marry. The habits which they had acquired during their priesthood generally induced them to continue in the service of their goddess for life. These virgin priests enjoyed at Rome the highest distinctions. When they went out a lictor walked before them; prætors and consuls when they met them lowered the fasces, and any criminal whom their eye caught sight of was immediately set free. In the theatres honorary seats were set apart for them. Augustus however prohibited their being present at the athletic games. Nero, on the other hand, abolished this law, and permitted them to be present, on the ground that the priestesses of Ceres were allowed to be present at the Olympic games. They had an official residence on the Via Sacra, and salaries derived from estates of the goddess, which were increased from time to time. A vestal virgin was considered to be of the same rank as the Flamen Dialis, and in a court of justice she could not be compelled to confirm her evidence by an oath. Their prayers were believed to be of particular efficacy, and wills and important documents were often intrusted to their keeping. They had also the privilege of being buried within the pomœrium.

The duties of the vestals were to keep the fire on the altar in the temple of Vesta burning, to guard the sacred relics and symbols preserved in the temple, to sprinkle the temple of the goddess every morning with water from the Egerian well, and various other things connected with the worship of Vesta. Besides the functions directly connected with the worship of Vesta, they had to perform in the course of the year various others. Thus, for instance, they conducted the mysterious worship of the Bona Dea on the first of May, and had to prepare the sacrifice to be offered on certain occasions. If ever the sacred fire in the temple of Vesta became extinct by the carelessness of a priestess, the neglect was atoned for by sacrifices, and the guilty vestal was scourged by the Pontifex Maximus on her naked back. The fire was not rekindled from a common fire, but from one produced by the Pontifex by the friction of two pieces of wood, or from the rays of the sun by means of a burning-glass, and the vestal caught it in a brass sieve by means of tinder, and thus carried it into the temple. On entering on the priesthood every vestal had to make a solemn vow to keep her chastity pure, like the goddess whom she served, during the years of her priesthood. A breach of this vow was regarded as a terrible crime and as a fearful calamity to the whole state. When a vestal was found guilty by the college of pontiffs, she was condemned to death without having the right of appeal to the people. As nothing but death could atone for her crime, and as it was nevertheless not allowed for any mortal to lay hands on the priestess of Vesta, she was buried alive in a subterraneous vault in the Campus Sceleratus, near the Colline gate. The mournful solemnity on such occasions was this. The guilty vestal was laid on a bier, tied fast with leather thongs, and covered in such a manner that not even the sound of her voice could be heard. In this position she was carried, as it were, in a funeral procession, accompanied by her friends and relations, amidst the dead silence of all the people, to the place of execution near the Colline gate. On her arrival here she was relieved of her bands, the Pontifex Maximus with uplifted hands said a mysterious prayer, and then conducted the veiled vestal to the ladder which led into the tomb. The executioner took her down and drew up the ladder; and during this process the pontiff and the other priests turned away their faces. In her tomb the vestal found a couch, a lamp, and some bread, water, milk, and oil. The tomb was closed and covered over with earth to a level with the rest of the ground. The man who had seduced a vestal was scourged to death. Notwithstanding the severity of the punishment, Roman history has on record several instances in which the punishment was inflicted. During the time of the republic the violation of chastity on the part of a vestal was always visited by the punishment prescribed by law, unless the goddess herself interposed in some miraculous manner to show that her priestess had been unjustly charged with the crime. Several interesting instances of this kind are related by the Roman historians. During the early part of the empire the conduct of the vestals appears to have become rather loose, since Domitian found it necessary to make the law concerning it more strict.

(Lipsius, *De Vesta et Vestalibus Syntagma*; Hartung, *Die Religion der Römer*, ii., p. 115, &c.; Göttling, *Geschichte der Römischen Staats verfassung*, p. 189, &c.)

VESTED REMAINDER. [REMAINDER.]

VESTRY is the name of that part of a parish church where the ecclesiastical vestments are kept; and inasmuch as meetings of parishioners have been usually held in this part of the church for parochial purposes, such meetings, duly convened, have acquired the name of vestries; so that even where a building remote from the church has been erected for parochial meetings, it is usually called the *vestry-room*. When the meeting is held in the church, or even in a building within the precincts of the churchyard, the ecclesiastical courts claim jurisdiction over the conduct of the parishioners.

By the common law all rated inhabitants of a parish have a right, either periodically or when specially convened, to meet in vestry for the affairs of the parish, and to vote the necessary pecuniary rates. But this common law right has been modified in many ways.

1. By custom, which has vested the government of some parishes in a select and usually a self-elected body of persons, probably the successors of individuals to whom the parishioners at some previous time delegated the management of their parish for a stated period, but who, by the indifference and neglect of their constituents, came to hold permanently the powers intrusted to them. The principal act for the regulation of these vestries is the 58 Geo. III., c. 69, but it does not extend to parishes within the city of London or borough of Southwark.

2. The act 10 Anne, c. 11 (for the purpose of erecting fifty new churches in London and its neighbourhood) appoints "a select vestry for each parish." The 59 Geo. III., c. 134, also permits the election of a select vestry out of the "substantial inhabitants of the district," parish, or chapelry; and several local acts have also created vestries.

3. The 59 Geo. III., c. 12 (Sturges Bourne's Act), enables general vestries to appoint special vestries for certain purposes; but they are little more than committees of the general vestries, to which they are responsible.

4. A fourth kind of vestry is created by 1 & 2 Wm. IV., c. 60 (Sir John Hobhouse's Act), but the adoption of this act is left to the discretion of each particular parish; rural parishes of less than 800 rated householders being excluded from its operation.

It is the duty of vestries to provide funds for the maintenance of the edifice of the church and the due administration of public worship; to elect churchwardens; to present for appointment fit persons as overseers of the poor; to administer such estates and other property as belong to the parish; and in some cases, under local acts, to superintend the paving and lighting of the parish, and to levy rates for those purposes.

The remedy for neglect of duty by a vestry is a *mandamus* from the Court of Queen's Bench, directed to the officer whose duty it would be to perform the particular act, or in some cases by an ordinary process against him, or by a process against the churchwardens out of the ecclesiastical courts.

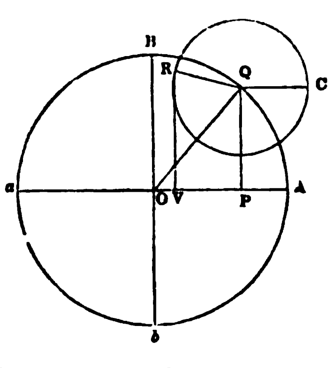
VIADUCT. A bridge erected over a valley, for the purpose of avoiding the necessity for carrying a roadway either by long inclines, by zigzags, or by precipitous descents, from a high level on one side of the hills bounding the valley, to a corresponding height on the other side. The conditions under which it is advisable to incur the expense of such a work, are principally when the annual cost of the traction upon the additional length of the inclined roads would exceed the interest upon the capital invested in the construction of the viaduct, added to the cost of its repairs; or when the rate of inclination of the roads is such as to render economical traction impossible. In roads designed to accommodate rapid traffic, for instance, inclines of 1 in 12 are inadmissible under any circumstances, and inclines of 1 in 30 are objectionable; but in either case the construction of a viaduct for the purpose of obviating the necessity for the incline must depend upon the number of the carriages likely to resort to it. In railway structures viaducts are more commonly employed than in common roads, on account of the greater influence of the inclinations of the roadway upon the traction; but even in them the use of viaducts can only be justified by considerations of economy.

In the article BRIDGES will be found a summary description of the dimensions of the most celebrated viaducts hitherto constructed. The principles upon which they are built have been discussed either in that article, or under ARCHES. It may suffice, therefore, here to add, that the skill of the engineer may be as usefully displayed in the execution of an embankment for the purposes of the roadway as in the construction of a monumental viaduct; and that the repairs of the former would be in all probability much less than those of the latter. The Highgate Archway, the North Bridge at Edinburgh, the Dee Viaduct near Chirk, the Crumlin Viaduct, the Aricia, Barentin, Chaumont, Dinting Vale, Elsterthal, Goeltzchthal, Malaunay, Ouse Valley, Portage, Tyne, viaducts, may be cited as the most remarkable works of this description.

VIBRATION. We have had in many articles to consider the effects of vibratory motions, but we have not yet given the explanation of the simple vibration, so as to enable a student with no very extensive knowledge of mathematics to form some conception of its character. The theory of the vibrations of the particles of an elastic fluid is the key to what is known of the phenomena of sound and light [ACOUSTICS; UNDULATORY THEORY]; and there is some reason to suspect, or at least those whose opinions are worthy of attention have suspected, that the causes of the sensible phenomena of heat, electricity, and magnetism will also be found in the vibrations of matter of some kind. All the particles of material bodies, even when solid, are probably in continual vibration; and it is certain that very slight disturbances will communicate sensible amounts of vibration to considerable distances, and this through all manner of different substances, from loose earth to compact stone, and through those in every kind of state, from the aëriform to the solid.

Little as may be known of most of the vibrations which are perpetually occurring, nothing is more certain, from the fundamental laws of mechanics, than that every such vibration in every individual particle is either made up of one or several motions of one particular kind, or of an exceedingly close approximation to such simple motion or combination of motions. It is not merely swinging backwards and forwards which constitutes a vibration; such a motion might certainly be so called, at the pleasure of any one, but another name must then be invented to designate that particular sort of vibration of which, and of no other, we have to speak in the first instance. The piston of a steam-engine, for example, when it is forced upwards with continually accelerated velocity until it strikes the top of the cylinder, and is then forced downwards in the same manner, does not show what is mathematically called a vibration; but take one of those more recent constructions, in which the steam is checked as soon as the piston has acquired momentum enough to carry it to the top of the cylinder, so that the force is nearly spent before it begins to return, and we have something to which the term vibration is much more nearly applicable.

The simple vibration, of which we have said all others may be compounded, is best imagined as follows:—Let a point Q revolve *uniformly* round a circle A Q a b, and from Q draw Q P perpendicular to A a. Then P moves over A a in the manner of a simple vibration; the whole vibration being from A to A again. At A and a the velocity of P is extinct, the whole motion of Q being perpendicular to A a; but at O the velocity is greatest, P then moving as fast as Q. If we measure the time t from the epoch of Q being at B, and suppose the motion of Q to be in the direction B Q A, and n to be the angular velocity of Q, we have (O P $= x$, O A $= a$) $x = a \sin nt$, while the velocity of P is $na \cos nt$, the acceleration of P is $-n^2 a \sin nt$, or $-n^2 x$, and if w be the weight of a particle at P, the pressure necessary to maintain it in this state of vibration is always directed towards O, and is, in units of the same kind as w,



$$\frac{n^2 x}{32{\cdot}1908} \times w,$$

if x and a be measured in feet, n in theoretical angular units [ANGLE], and t in seconds [VELOCITY]. If T be the number of seconds in the whole vibration from A to A again, we have $n = 2 \times 3{\cdot}14159 \div \mathrm{T}$, and the pressure is $1{\cdot}2264\, x w \div \mathrm{T}^2$. The pressure, it appears, requisite to maintain a simple vibration must be always in a given proportion to the distance of P from O, and always directed towards O; and the relation between the pressure at a given value of x and the time of vibration is wholly independent of a, the *excursion* of the particle. For the mechanical reason of this property, see ISOCHRONISM. To form a more convenient expression, let N be the number of vibrations in a second, and let x be measured in hundredths of inches instead of in feet; then $\mathrm{T} = 1 \div \mathrm{N}$, and for x we must write $x \div 1200$, which gives for the pressure $\cdot 001022\, \mathrm{N}^2 x w$. For example, if a particle vibrate only 100 times in a second, which is not much [ACOUSTICS], and have an excursion of one five-hundredth of an inch ($\mathrm{N} = 100$, $x = \cdot 2$), the force of restitution at the extremity of the excursion is more than twice the weight of the particle. By this formula it is easy to get a just idea of the greatness of the molecular forces required to produce those vibrations which are constantly excited in sonorous and other bodies.

If we suppose a second vibration to be communicated to P, in the same line, *and of the same duration*, but whether of the same extent or not does not matter, the compound vibration is only equivalent to another simple vibration. Let a circle move with Q, and in that circle let a point (R) revolve uniformly, and let R V be perpendicular to O A. Then, while P vibrates about O, V performs a vibration in the same time relatively to P; or a spectator who does not see the motion of P, will see no motion in V except a vibration about P. Now it is easily shown that R not only describes a circle about Q, but also actually describes either a circle in space, about the centre O, or an ellipse, in the manner presently explained. And V, vibrating about P, which itself vibrates about O, does, if these vibrations be of the same duration, nothing but vibrate about O. Mathematically, this is easily obtained as follows:—Let the angles A O Q and C Q R (Q C being parallel to O A) be at some one moment α and β, and let O Q $= a$, Q R $= b$, and let the time be measured from the instant at which the angles are α and β. Then we have

$$x = a \cos (nt + \alpha) + b \cos (nt \pm \beta),$$

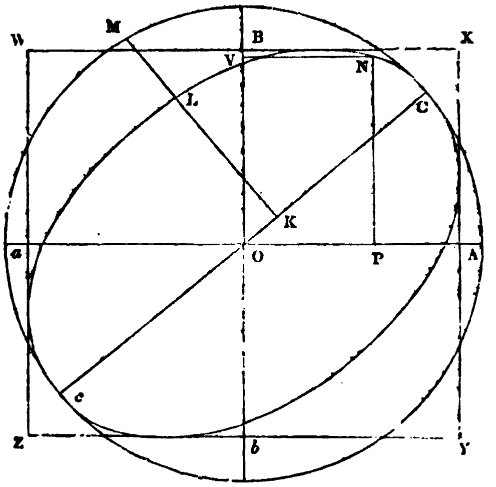
the sign + being used when the circular vibrations are in the same; — when they are in opposite, directions. This is equivalent to $x = l \cos (nt + \lambda)$, provided l and λ be found from

$$l \cos \lambda = a \cos \alpha + b \cos \beta \;,\; l \sin \lambda = a \sin \alpha \pm b \sin \beta;$$

and the joint vibration is one of the excursion l, and such that the angle is λ when the angles of the component vibrations are α and β. It is easy to show in like manner that any number of vibrations whatsoever, made in the same times and in the same lines, are not distinguishable from one single vibration, of the same duration and in the same line.

Again, it is easily shown that a vibration which is represented in direction and excursion by the diagonal of a parallelogram is the compound effect of two vibrations of the same duration, represented in direction and excursion by the two sides of the parallelogram, if the particles of the component vibrations begin to describe the sides at the same instant as the particle of the resultant vibration begins to describe the diagonal; and the same thing may be shown of the diagonal of a parallelopiped and its three sides. Hence any number of vibrations of equal times about any lines drawn through one point may each be decomposed into three in the direction of three given axes passing through that point, and those in the several axes may be compounded together into one. The student who appreciates the similarity of the laws by which velocities, pressures, and rotations are compounded and decomposed, will see that to the list must be added vibrations. But the only vibrations which bear the application of these rules are those of equal duration.

Let us now suppose that any number of vibrations of equal times, and about the same point, are reduced to three, in the directions of three axes of x, y, and z. When $a \cos \xi$ represents the distance of a vibrating particle from its centre of vibration, let the angle ξ be called the *phase* of the vibration. If the three vibrations be always in the same phase, the diagonal of the parallelopiped described on the three excursions represents the direction and excursion of the resulting vibration, which is simple and rectilinear. But if the simultaneous phases be not the same, so that $x = a \cos (nt + \alpha)$, $y = b \cos (nt + \beta)$, $z = c \cos (nt + \gamma)$, represent the simultaneous distances in the three vibrations, and also the co-ordinates of a point which is affected by them all, the particle, thus triply vibrating, does not move in a straight line, but in an ellipse. Let us consider two vibrations in a plane, and let A a and B b be their double excursions about the common centre O. The axes in the figure are drawn at right angles, but any angle will do equally well. Draw the parallelogram W X Y Z, which always contains the particle, and suppose that P and V are contemporaneous positions in the two vibrations, whence N is one of the positions of the particle. Through N can be drawn two ellipses, having the centre O, and touching all the four sides of the parallelogram W X Y Z. The particle must describe one or other of these ellipses: one when P and V are both leaving the centre or both returning to it; the other when one is leaving the centre and one returning to it. In the figure, and supposing C N c to be the direction of motion, V is leaving, and P returning to, the centre. And if C M c be the circle described about this ellipse, and K L M be always perpendicular to C c, the law of the motion of the particle L is that M moves uniformly round the circle, or K moves through a simple vibration. This is exactly the law of motion shown by Newton to obtain when the particle L is attracted towards O by a force which varies as its distance from O; and mechanical considerations might easily be used to establish the whole theorem. If the vibrations be thus compounded for each pair of axes, three ellipses are obtained on the three co-ordinate planes, which are the projections of the ellipse which the particle describes in space.



We may attempt to compound two different vibrations on the same line, that is, two vibrations of different durations. If in the first figure we suppose the angular velocity of R round Q to be different from that of Q round O, we see that R describes a trochoidal curve, and supposing such a curve to be described by uniform circular motions, the motion of the projection of R upon the line of vibration will show the effect of the two vibrations. Some simple instances may be readily obtained from the diagrams in the article cited; but an attempt at a description of the multifarious effects of even two vibrations would baffle all human power of classification.

We now proceed to some account of the principal mechanical considerations connected with vibrations. If any system whatsoever be slightly disturbed from a position of stable equilibrium, every particle makes an effort to return to that position; and it can be shown that the force of restitution varies as the distance from the position of equilibrium, so that all the particles perform either simple vibrations, or motions compounded of simple vibrations. Not that it is accurately and geometrically true that the force of restitution always varies as the distance from the position of equilibrium, but only exceedingly near to it. The consequence of the restitutive force is, that the system, in returning to its position of equilibrium, acquires velocity, and the several particles pass through or near to their positions of equilibrium with their several velocities, until the force of restitution, which begins to act in a contrary direction the moment the position of equilibrium is passed, destroys the acquired velocity, and causes the particles to return. The same vibration is then repeated, or rather would be repeated if there were no retarding forces: as it is, the resistance of the air, &c., continually diminish the extent of the vibrations, until at last they become insensible. But it can be satisfactorily shown that these resistances have no sensible tendency to alter the times of the vibrations; and few persons are aware how much of their comfort depends upon this circumstance. Whenever a sound is produced, a musical note generally accompanies it; the sound is the consequence of the vibrations excited in the disturbed system, and the permanency of its musical pitch is the consequence of these vibrations being all made in the same time, or very nearly so. The air does not retain the vibrations communicated to it, but passes them on, so to speak; and it is therefore an agent which communicates the successive vibrations of a disturbed body just as they are communicated to it. If the vibrations gradually slackened in their *times*, as they do in their excursions from the effect of the resistances, the consequence would be that there would be no sustained notes, but every sound would be a sliding chromatic descent, like the cry of some animals, which are therefore considered very annoying neighbours; and most musical instruments would be rendered unusable.

There is a principle in mechanics which is called that of the *coexistence of vibrations*, and sometimes the *superposition of vibrations*, which seems to be only a particular case of what might be called the coexistence or superposition of small changes of any kind. If a set of small vibrations be given to any system, solid or fluid, the disturbance of any particle at any one instant, arising from the united effect of the vibrations, will be the sum or difference of the disturbances arising from the several different vibrations, according as they are in the same or opposite directions. This is not strictly true in any case, but it is very nearly true when the vibrations are small, and the more nearly so the smaller the vibrations are. For instance, two stones are dropped into water at two different places, and at a certain time, on a certain part of the surface, the resulting waves cross one another. If there be a particle which is at the same time raised on both waves, a tenth of an inch say, from one only, and three-tenths of an inch from the other, that particle will altogether be raised four-tenths of an inch, or insensibly near to it. Thus the effects of the two waves travel without any apparent interference with each other, and the eye can easily follow any one wave, even though a dozen disturbances should have been excited at the same time. A handful of small pebbles thrown into smooth water will show the coexistence of the resulting waves very satisfactorily; and it is curious to observe how readily the non-interference of the several disturbances is seen when looked for, so readily, that it never is looked for unless the attention be specially directed to it.

VIBRATIONS OF HEAT. [HEAT.]

VICAR (from the Latin *vicarius*, "one who discharges the functions of another"). The origin, constitution, and functions of this class of ecclesiastical persons have been already fully treated of. [BENEFICE.] One part of the subject is alone omitted in that article, namely, the dissolution of vicarages. Of this it suffices to say that since the 13th Elizabeth, c. 10, the property neither of a vicarage nor of any other ecclesiastical office can be alienated, and that although a vicarage may be dissolved, as already described, by the vicar acquiring all the rights of the parson, yet the appropriator, whether lay or ecclesiastical, cannot dissolve the vicarage by alienating its property or by neglecting to present. A vicarage may be dissolved if the parson or appropriator presents the clerk to the benefice, whether by design or by accident: it may also be dissolved and become a parsonage, or, to speak technically, disappropriate, by the dissolution of the corporation to which the benefice is annexed. Thus if a college which is the appropriator of a certain benefice is dissolved, the vicar becomes entitled to the great tithes, and his vicarage is thenceforward converted into a rectory. [BENEFICE; TITHES.]

VICAR APOSTOLIC. [CATHOLIC CHURCH (Roman).]

VICARAGE. [VICAR.]

VIENNA LAKE. [COLOURING MATTERS.]

VIENNA, TREATY OF. [TREATIES, CHRONOLOGICAL TABLE OF.]

VILL. [TOWN.]

VILLEIN, or VILLAIN, denotes a species of bondman subject to his feudal superior. The word is from the low Latin form *Villanus*, which is from the Latin word *Villa*. In England, during the Anglo-Saxon period, a large part of the people appear to have been in a servile condition, either as domestic slaves or cultivators of the land. The power of the master among the Anglo-Saxons, though very extensive, had some limits. If a master beat out the eye or the tooth of his slave, the slave was entitled to his freedom; if he killed him, he paid a fine to the king, unless the slave lived a day after the wound was inflicted, in which case the offence was unpunished. The Norman Conquest did not materially alter the state of slavery in England. The lands were transferred to Norman masters, and the slaves passed as part of the property. After the Conquest there were four classes of slaves: 1, Villeins in gross, who were the personal property of their lords, and performed the lowest household duties. They were very numerous, and were frequently sold and even exported to foreign countries. (Walsingham, 'Hist. Ang.,' p. 258.) 2, Villeins regardant, or prædial slaves, who were attached to the soil, and specially engaged in agriculture. These were in a better condition than villeins in gross, were allowed many indulgences, and even, in some cases, a limited kind of property; yet the law held that the person and property of the villein belonged entirely to his lord, the rule being the same as that in the Roman law, that whatever was acquired through the slave was acquired by the lord. 3, A class called *Cottarii* is mentioned in Domesday Book; and 4, in the same book a class called *Bordarii*. But the first two classes in fact comprised all the villeins.

The legal condition of villeins in the reign of Edward IV., when Littleton wrote his Book of Tenures, appears from that work, Sections 172-208.

In England a few instances of prædial servitude existed so late as the reign of Elizabeth, and perhaps at a still later period. (Barrington, 'On the Statutes,' 274; Hallam's 'Middle Ages,' vol. i.) In some parts of France it existed down to the time of the Revolution. [SLAVERY.]

(Bracton; Littleton; Coke's *First Inst.*; Reeves, *Hist. of English Law*; Blackstone's *Commentaries*.)

VILLEINAGE was a base tenure of land. This tenure was founded on the servile state of the occupiers of the soil [VILLEIN], who were allowed to hold portions of land at the will of their lord, on condition of performing base and menial services. Where the service was base in its nature, and uncertain as to time and quantity, the tenure was called pure villeinage; but where the service, though base, was certain and defined, it was termed privileged villeinage, and sometimes villein-socage.

Villeinage is generally supposed to be the origin of copyhold tenure. [Copyhold; Enfranchisement.]

VINCULUM, a name given in algebra to the line, brackets, parentheses, or other symbol, by which various terms are compounded into one, or supposed to be so compounded, in order that the result may be further operated on. As in—

$$\overline{a+b+c}\,x\;,\;(a+b+c)\,x\;,\;\{a+b+c\}\,x\;,\;\&c.,$$

which are, by the vinculum, prevented from being confounded with $a+b+cx$.

VINE. [Vineyard.]

VINEGAR, MEDICAL USE OF. [Acetic Acid.]

VINEGAR-MAKING. Vinegar is a dilute acetic acid obtained by the vinous fermentation. [Fermentation.] In countries which produce wine, vinegar, as its name imports, is obtained from the acetous fermentation of wine; but in this country it is usually procured from malt, and the process employed resembles the first stage of the brewer's operations. [Brewing.] The malt is ground and mashed with hot water. The wort, after being cooled, is transferred to the fermenting tun, where, by the addition of yeast, it undergoes the acetous fermentation; and when this is over, the liquor is transferred to small vessels, which are kept warm by means of a stove: in this it remains for a shorter or longer period, according to the temperature of the stove and the strength of the liquor. The process of acetification is assisted by introducing into the casks with the wort what is called *rape*, the residuary fruit which has served for making domestic wines, or has been preserved by the vinegar-maker from one process to another in his own factory. The use of the rape is to act as an acetous ferment, and thus induce sourness in the wash, it being well impregnated with vinegar and continually kept sour. Acetification is sometimes carried on by transferring the wort, after it has undergone the vinous fermentation, into casks, the bungholes of which are left open and loosely covered with tiles; the casks are then exposed for a long time to the air. But the use of stoves has greatly superseded this mode, and has abridged the time of the operation and rendered it less liable to failure. The vinegar, after it has reached its greatest degree of sourness, is rendered clear and fit for use either by subsidence or the employment of isinglass. The manufacturer is allowed by act of parliament to mix $\frac{1}{1000}$ of its weight of sulphuric acid with vinegar; and what is termed by the Excise *proof vinegar* contains 5 per cent. of real acetic acid.

Vinegar may be prepared in small quantities from the fermentation of a solution of sugar mixed with yeast; or it may be obtained by the fermentation of various fruits: thus, the juice of good apples contains a sufficiency of sugar to afford tolerably good vinegar without any addition.

In France, vinegar is made from poor wine, and there are two kinds: the white, prepared from white wine; and the red, by the acetification of the red wine. These are finer flavoured and somewhat stronger than the malt-vinegar of this country.

Vinegar-works in this country are but few in number; they require a large amount of space and the investment of much capital. There are about half-a-dozen of them in the metropolis. At most of those in this country, as has been said, malt is the kind of grain employed; but the vinegar-maker holds himself free to the use of unmalted grain, if price and other circumstances should render it desirable, or saccharine substances instead of grain. From whatever substances the *gyle* is produced, the conversion of it into vinegar is managed nearly in the same way. Where the *rape* is not to be procured easily, the vinegar-maker uses wood-shavings, straw, or even tanners' spent bark; but the rape is so far preferable, that a large expenditure is sometimes incurred to obtain a sufficient quantity: hence the advantage of carrying on the "British wine" manufacture and the vinegar manufacture in the same establishment (which is sometimes done); refuse raisin-stalks and skins result from the making of raisin-wine. Vinegar is known by certain numbers, such as Nos. 18, 20, 22, and 24; these originally represented, it is supposed, the number of pence per gallon at which the vinegar was sold; and although the price no longer agrees with the numbers, they have been retained as designations for different kinds or strengths of vinegar. The quantity made in the United Kingdom is not now known; some years ago it was about 3,000,000 gallons annually.

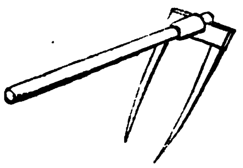
It may be well to remark that, in country districts, much vinegar, but of inferior quality and insipid flavour, is made by the aid of the singular substance known as the *vinegar-plant*. This substance is rather a scum than a plant. In Staffordshire, a vinegar-plant is thus produced:—About a quarter of a pound of sugar and half a pound of treacle are put into three quarts of water; the solution is simmered, poured into a jar, covered up, and kept in a warm corner for six weeks: an inferior kind of vinegar is formed, and on the top of it is a scum, with very much the appearance of tripe, constituting the so-called vinegar-plant. Vinegar can thus be made from a sweet liquor alone; but when a vinegar-plant is once produced, it greatly quickens the process of vinegar-making, without materially altering the proportions of the other ingredients. A gallon of vinegar is thus made at a cost of about sixpence. During the process the vinegar-plant thickens, by the formation of a new layer on the under surface; the two layers may easily be separated, and each will be available for a further process of vinegar-making, and this three or four times over. The substance is a kind of fungus, whitish in colour, semi-transparent, jelly-like, and sometimes an inch in thickness. In some country places strong pickling-vinegar is made by cottagers, by mixing cowslip flowers and stalks with sugar and water, adding a little yeast, closing it up, and allowing it to remain in a warm place for several weeks.

VINEYARD. The vine only thrives in particular climates, where the autumns are not excessively hot, nor the springs subject to late frosts. It has been observed in France, that the line which marks the northern boundary of the vineyards is not parallel to any circle of latitude; but that it lies obliquely, advancing more to the north on the eastern boundary of the country than on the western. It seems to depend more on the nature of the climate in spring and autumn, than in summer and winter. A hard frost at the time the sap is quiescent has no bad effect on the vine, but rather the contrary; while a late frost in spring disappoints all the hopes of the vine-grower. There was a time when the vine was cultivated in England for the purpose of making wine; but whether the climate is altered, or the foreign wines have superseded the sour home-made wines, no one now attempts to cultivate the vine except for the purpose of obtaining grapes for the table, and the mode of cultivation is a branch of horticulture.

It may however be interesting to know how the vine is cultivated in the countries which produce good wine; of which France is one of the principal and nearest in climate to England. The vine grows best in a soil where few other shrubs or plants would thrive, and it seems a wise distribution of Providence, that where there is the best soil for wine, there it is the worst for wheat, and *vice versâ*. The vine delights in a deep loose rocky soil, where its roots can penetrate deep into fissures, so as to insure a supply of moisture when the surface is scorched by the sun's rays. On the steep slopes of hills towards the south and sheltered from the north-east, the grapes attain the greatest maturity, and the vintage is most certain. So great an influence has a favourable exposure, that in the same vineyard the greatest difference exists between the wine made from one part and that made from another, merely because there is a turn round the hill, and the aspect varies a very few degrees. A change of soil produces a similar effect. The famous Rhine wine called Johannisberg, when made from the grapes which grow near the castle, is worth twice as much as that made a few hundred yards farther off. Here both soil and aspect change. The *Clos de Vougeau*, which produces the finest Burgundy, is confined to a few acres; beyond a certain wall the wine is a common Burgundy, good, but without extraordinary merit.

The best vineyards in Europe formerly belonged to monasteries, and the quality was then thought of more importance than the quantity: of late the demands of commerce have made the quantity the principal object; and to this the quality is frequently sacrificed.

When a vine is first established on any spot where none grew before, the first thing is to prepare the ground for planting. In steep places, where the soil might be carried away by rains in winter or spring, terraces are formed by building massive stone walls along the slope, and levelling the soil behind them. The walls serve to reflect the heat, and form a shelter to the vine below. Thus a whole hill is sometimes covered with terraces from top to bottom, and there the wine is generally good, if the exposure be favourable. Limestone, gravel, or coarse sand, with a small mixture of clay, forms a good soil for a vine; vegetable substances alone should be used to enrich it, such as the leaves and tendrils of the vine, the residue of the grape when pressed, and, failing these, the leaves of trees collected when green, and formed into a compost with earth. The ground should be well trenched, if it will admit of it, or loosened with the mattock and pickaxe. The different parts of the soil should be intimately mixed, keeping some fine earth or soil at top to set the plants in. When the ground is prepared, holes are dug in rows four or five feet wide, at the same distance from each other, so as to alternate; some of the finest of the soil is put into each hole, and the vine-plants, which have been rooted in a nursery, or else simple cuttings, are carefully inserted, pressing the mould round the roots and levelling the earth round them. Rooted plants will bear the second or third year, but cuttings take a much longer time. The season for planting is during the winter, when the weather is open. If cuttings are used, they are taken off the vine on which they grew at the usual time of pruning after the vintage; a piece of the preceding year's wood is left on the cutting, and when it is planted, the end where the old wood is left is bent or twisted to facilitate its striking: three or four eyes are buried, so that the end is a foot at least under ground. If the plant is already rooted, care is taken not to wound or bend the roots, but to spread them out and cover them with mould. During all the time that the vine is growing, the ground must be regularly cultivated and kept perfectly clear of all weeds. The usual instrument of tillage in stony and rocky soils is a two-pronged fork fixed in a short handle, at an angle less than a right angle with the prongs, which are a foot long, and very strong, like a double pickaxe (see figure, col. 631). This is struck into the ground and then drawn towards the workman, while the handle is lifted, which acts as a lever in raising the soil. The roots are by this means enabled to spread through the soil in search of moisture and food. The next year it is usual to prune the young vine down to one or at most two eyes or buds; but some experienced vine-dressers recommend deferring this operation to the second year, by which although the vine will not be so forward in fruiting, it will be much strengthened, and fully repay the apparent loss of time in the end.



In the third year the vine is trained, that is, the shoots are tied to upright stakes planted at each root, or they are laid in an arch and tied from one root to another along the ground. In southern climates trees are planted at a certain distance from each other, and the vine, planted at their foot, is allowed to run up their branches, from which it is led in festoons from tree to tree, while the head and branches of the tree are cut off to prevent too much shade. This is by far the most elegant mode of training the vine; but in France the stakes and the low training are the only methods suitable to the climate. The pruning is generally done in the beginning of winter.

When vineyards are established in the plains, where sometimes, as those of Medoc, they produce very good wine, the intervals between the plants can be stirred by the plough, although forking and digging by hand is more common; hoeing is as necessary in a vineyard to destroy weeds as it is in a field of turnips or any other crop sown in rows. Wherever a vineyard is overrun with weeds, you may be sure that there is no good wine, and much poverty in the proprietor. The pruning of a vine in bearing, the object of which is to produce much fruit without weakening the plant, can only be learnt by experience and practice; much of the success of a vineyard depends on this operation. In the best vineyards no manure is used, except that which we mentioned before, of leaves and tendrils; but some soils require to be recruited, and without manure would produce little or no wine. In this case there is no alternative, and composts must be formed, as is done in common cultivation, with animal and vegetable substances mixed and decomposed. Manure from the cow-house should be mixed with virgin earth from pastures and meadows, and laid in small heaps in the intervals between the rows. It may be left a little while, if it have any rank smell, and then forked in round the roots; the more it is decomposed the better. Many a vineyard has lost its reputation after having been abundantly manured. The Johannisberg was much reduced in value, after having been dunged, while in the possession of General Kellerman.

After a certain time, which differs in different situations, the vine becomes less productive from the exhaustion of the soil, as is the case when the same crops are repeatedly sown in the same ground: this depends on the depth of the soils. All perennial plants shoot out their roots farther and farther every year in search of fresh earth, and it is by this means that trees flourish for a long time on the same spot; but if the roots are prevented from spreading, or, the plants being too crowded, their roots interfere, a diminution of vigour is the consequence. So it is with the vine. In some situations, where the roots strike in crevices of rocks in which rich earth has accumulated, the vines will continue in vigour for many years; but where their progress is arrested by a solid rock or substratum, they will in time show signs of exhaustion. In this case the remedy is the same as for land bearing corn. A fallow, or rest, as it is usually called, is necessary, together with the addition of such manures as shall restore the lost fertility. For this purpose a portion of the oldest roots are dug up every year, and the ground trenched or loosened two feet deep or more with the mattock, to expose it to the influence of the atmosphere. A compost is prepared with sods taken from pastures, or any virgin earth which can be procured; this is mixed with some lime and turned over several times, to rot all the roots and grass which may be in it, and to make it a uniform and rich mould. Holes are now made, exactly as when a new vine is planted, and in each of them a basket or barrowful of earth is thrown; in this the new plants or cuttings are planted to produce new vines in due time: thus the vineyard is gradually renovated. The proportion thus fallowed every year depends on the natural duration of the vine in that particular situation. In inferior soils one-seventh is thus renewed every year, in some a twentieth part is sufficient, and there are vineyards which have never been renewed in the memory of the present generation, but these are few in proportion to the rest.

Vineyards for several years past, and in almost every country, have been subject to attacks of the *Oidium Tuckeri*, a destructive fungus that has in many cases entirely ruined the vineyards. No perfect remedy has been yet found for the attacks of this fungus, but the most successful hitherto has been the sprinkling of the plants with powdered sulphur. [Vitis, in Nat. Hist. Div.]

VINIC ALCOHOL. [Alcohol.]

VINOUS FERMENTATION. The process by which sugar, in the presence of yeast, is transformed into alcohol and carbonic acid. [Ferment.]

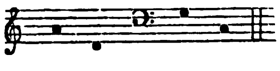
VIOL, an ancient musical instrument, which is traced back as far as the 8th century, and may be considered as the parent of all modern instruments of the violin family.

The Viol was a fretted instrument, of three sorts—treble, tenor, and base, each furnished with six strings, and played on by a bow. The Treble Viol was rather larger than our violin, and the music for it was written in the treble clef. The Tenor Viol was in length and breadth about the size of the modern viola, but thicker in the body, and its notation was in the soprana or C clef. The Base Viol scarcely differed in dimensions from our violoncello: the music for it was written in the base clef.

" Concerts of viols," says Sir J. Hawkins (iv. 339), " were the usual entertainments after the practice of singing madrigals grew into disuse; and these latter (that is, viols) were so totally excluded by the introduction of the violin, that at the beginning of the 18th century Dr Tudway was but just able to give, in a letter to his son, a description of a Chest of Viols. He tells us that it 'was a large hutch with several apartments and partitions in it, each lined with green baize. Every instrument was sized in bigness according to the part played upon it; the least size played the treble part,' &c. The humorous Thomas Mace, of Cambridge, in his 'Music's Monument' (p. 245), says, 'Your best provision (and most complete) will be a good chest of viols, six in number, namely, two bases, two tenors, and two trebles, all truly and proportionably suited. Of these the highest in esteem are by Bolles and Ross (one bass of Bolles' I have known valued at 100*l*). These were old; but we have now very excellent workmen, who (no doubt) can work as well.' "

VIOL DA GAMBA (or properly, *Viola di Gamma*), that is, the *leg-viol*, so called from being held between the legs, was the last survivor of the family of viols, and did not entirely fall into disuse till the latter part of the 18th century. In form and dimensions it resembled the modern violoncello, but had six strings. The tone was nasal and disagreeable, and the instrument is so thoroughly supplanted by the violoncello, that in all likelihood its restoration will never be attempted.

VIOLA, or TENOR-VIOLIN, a larger kind of violin, to which the part between the second violin and base is assigned. It has four gut strings, the two lowest covered with silver wire, which are tuned A, D, G, and C, an octave above the violoncello; or



VIOLA ODORATA, *Medical Properties of.* Though every part of the sweet-scented violet possesses some property which renders it useful, it is chiefly the qualities of the flower which entitle it to notice here. The petals possess a colour and an odour which render them useful. The former serves as a chemical test, the latter recommends the preparations to the sense of smell by its pleasantness. It is not always innocuous, as very sensitive persons have sunk under its influence. Violets should not be kept during the night in sleeping-rooms.

The petals may either be employed fresh to form a syrup, or preserved dry, and used when required. The drying must be carefully performed, to preserve the colour, and afterwards kept in the dark, either in bags of thick brown paper, or bottles lined with paper. The syrup is used more as a chemical test, to show by the action on its colour the presence or absence of acids or alkalies, than as a medicine. It ought, for either purpose, to be perfectly pure; but few things are more sophisticated. Its medical properties are slight, if any. It is reputed to be a mild, safe laxative, mixed with almond-oil, for even the youngest children.

The seeds are demulcent, and they, as well as the leaves, are emollient, from the mucilage they contain. They are both used for fomentations and cataplasms. The root is emetic and purgative. It contains an alkaloid termed *Violina.* This resembles Emetina, and can be used like it.

Viola tricolor, or Pansy, is recommended in the skin disease of children called *Crustalactea*, or *Porrigo larvalis.* It communicates, as does a Spanish sweetmeat or preserve, a peculiar odour to the secretion from the kidneys. The occurrence of this odour is therefore no criterion of a beneficial action over the disease. *Viola primulæfolia*, Linn., *V. ovata*, Rafinisque, is reputed good against the bite of the rattlesnake.

Ionidium Ipecacuanha is the emetic of Brazil, while *Ionidium microphyllum*, of Quito, is most useful in *Elephantiasis.*

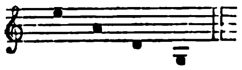
VIOLET. The botanical characters are given in the Nat. Hist. Div., under Viola; but there are many varieties. There are hardly any species of violet that do not deserve cultivation on account of their beauty; but the varieties of *odorata*, the sweet-scented species, and *tricolor* [Pansy], are the chief favourites. They are all readily raised by seeds, or by parting the roots. The annuals may be sown on the open border or on rockwork; the perennials, on a mixture of loam, peat, and plenty of sand. The shrubby kinds are best propagated by cuttings, and the herbaceous by dividing the roots. The Neapolitan violet, which is white, is somewhat more difficult to raise in this country. The best way is, in May, after they have done flowering, to sift some light soil over the plants to the depth of a couple of inches, in order to promote the production of runners, but leaving as much of the foliage as possible exposed to the air. In about six weeks the runners have formed roots. Then take up the old plants and select the best runners. These are to be planted in a bed formed of two parts of turfy loam and one part of leaf mould, placed so as to be shaded by trees, but well exposed to the air. A trench is to be made by removing the soil to a depth of about four inches, which is to be filled up to a level with leaf mould, over which the removed soil is to be placed. Upon this the runners are to be planted, at distances of about four inches, the rows being at least seven inches apart. They are then to be well watered, and the watering repeated frequently during the summer months. In September they will have become strong enough to be removed, with good bulbs at their roots, and may be transplanted to frames under glass, well watered and shaded from the sun, for about a week, when they will have rooted well again, and may be freely exposed to the air. By October they will be in bloom, and will continue flowering till May.

VIOLET SAUNDERS. [Colouring Matters.]

VIOLIN. The colouring matter of violets. Its composition is unknown. This name has also recently been applied to one of the numerous and beautiful colouring matters derived from aniline. Dr. David Price prepares this colour by heating an aqueous liquid containing two equivalents of sulphuric acid and one equivalent of aniline to the boiling point, and then adding one equivalent of binoxide of lead, boiling the mixture for some time and then filtering it whilst hot. The filtrate is of a dark purple hue, is boiled with potash both to separate the excess of aniline and also to precipitate the colouring matter. When all the free aniline is volatilised the residue is thrown on a filter and slightly washed with water, and then dissolved in a dilute solution of tartaric acid. This solution after filtration is evaporated to a small bulk, re-filtered, and then precipitated by means of an alkali. Thus obtained violin presents itself as a blackish purple powder, which, when dissolved in alcohol and evaporated to dryness, appears as a brittle, bronze-coloured substance, similar to aniline purple, but possessing a more coppery reflection. It is nearly insoluble in water, very soluble in alcohol, and insoluble in ether and hydrocarbons. These solutions possess a colour somewhat similar to that of the field violet. Concentrated sulphuric acid dissolves it, forming a green solution, but excess of water restores it to its original colour. Reducing agents deprive it of its colour, which is, however, restored by the action of the atmosphere. Tannin produces an insoluble compound with it.

VIOLIN (*Violino*, It., *a small viol*), a musical instrument known, in some shape, as used with a bow, in nearly all parts of the world, is by many antiquaries believed to have existed in very remote times. Be that as it may, the Abbé le Beuf has produced a strong proof that the violin—or perhaps rebec [Rebec]—acted on by a bow, was known in France during the 8th century, and thus has left little if any doubt of the use of the instrument from that period, however uncertain we may be as to its previous existence. The Welsh cruth, or crwth, or crowd, which pretends to great antiquity, seems originally to have partaken more of the form and character of the harp than of the violin. The cruth of a later period was, however, certainly a violin, with gut strings, and played on by a bow. (See 'Hudibras,' I. ii. 105.)

The modern violin has four gut strings, the last, or lowest, covered with silver-wire. These are tuned in 5ths, E, A, D, G; or,



M. Baillot, one of the finest modern performers, in his 'Méthode' for the violin, adopted by the Conservatoire de Musique, says that the compass of the violin exceeds three octaves. Supposing this to signify three octaves and a half, the legitimate extent of the instrument will be from G, the fourth space in the base, to the octave above the second added line in the treble. But we cannot refrain from expressing our wish that violinists would confine themselves within a more limited compass. The highest sounds of the instrument are disagreeable to most ears; are often harsh, and almost always squeaking; and though they display a kind of mechanical skill in the performer, they, in most instances, betray his vanity and want of true taste.

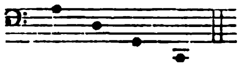
When complete, says M. Otto (instrument-maker to the court of Weimar), in his 'Treatise on the Construction, &c. of the Violin,' this instrument consists of fifty-eight different parts, or pieces: but such small divisions are not indispensably necessary, for in many instruments of a cheap description the parts are not so minutely divided. "The wood is generally of three sorts. The back, neck, sides, and circles are of sycamore: the belly, bass-bar, sound-post, and six blocks, of deal: the finger-board and tail-piece of ebony." The finest violins now in use were made by one family, living in Cremona. The oldest came from the hands of Hieronymus Amati, at the commencement of the 17th century. He was followed by Antonius Amati, about the middle of that century; and succeeded by Nicolas Amati, towards the end of the same. To these is to be added Antonius Straduarius, of Cremona also, who was contemporary with the two latter of the Amatis. And last, Joseph Guarnerius, at the beginning of the 18th century. "All their instruments," M. Otto adds, "were constructed after the simplest rules of mathematics (?), and the six which came into my possession *unspoilt*, were made after the following proportions:—The belly was thickest where the bridge rests; then it diminished about a third at that part where the *f* holes are cut; and, where the belly rests on the sides, it was half as thick as in the middle. The same proportion is observed in the length. The thickness is equally maintained all along that part on which the bass bar is fixed: thence to the upper and under end blocks the thickness decreases to one-half, so that the cheeks are three-fourths the thickness of the breast, and the edges all round only one-half. These proportions are best adapted for imparting a full, powerful, and sonorous tone. The back is worked out much in the same proportion as the belly."

Steiner, of Apsam, is also celebrated for his violins. "They differ," M. Otto tells us, "from the Cremonese, both in shape and tone. They are higher modelled, and their proportions of strength are calculated quite differently. A Cremonese has a strong reedy tone, something like that of a clarionet, while a Steiner approaches that of a flute." The same author also gives the names of many German violin-makers; but as they are not generally known out of their own country, we cannot afford any space to them, but refer our readers to the translation of M. Otto's work, by Mr. Fardeley of Leeds.

Many years ago, M. Savart constructed a violin with straight sides, and differing in several other particulars from the ordinary instrument. It was tested by musicians, and reported on most favourably by M. Biot ('Annales de Chimie et de Physique,' tom. xii.). It would appear from this report, that a first-rate violin may be constructed for a few shillings, provided the parts be selected and put together on the acoustic principles therein described. We are unable to say what is the cause of failure, but it seems that out of Savart's own skilful hands the experiment has not succeeded.

VIOLIN STRINGS. [Catgut.]

VIOLONCELLO (a diminutive of *Violone*, Ital., a *contra-basso*, or double-base), a musical instrument of four gut strings, the two lowest covered with silver-wire, and tuned in 5ths, A, D, G, and C; or,



This fine rich instrument is an improvement of the *viol da gamba*, the latter having formed one of the family of viols. [Viol; Viol Da Gamba.] England may justly claim the merit of having given birth to the best performers on the violoncello that Europe has produced.

VIRGINAL, a musical instrument now entirely disused. It is described by Dr. Burney as "a keyed instrument of one string, jack, and quill to each note, like a spinet, but in shape resembling the present small piano-forte. It," he adds, "has been imagined to have been invented in England during the reign of Elizabeth, and to have been thus denominated in honour of that virgin princess; but a drawing and description of it appeared in Luscinius's 'Musurgia' before she was born." ('Hist. of Music,' iii. 5.) The compass of the virginal was from the second added line below the base to the second added line above the treble—or four octaves.

VIRGO (Constellation), the sixth constellation in the zodiac, surrounded by Libra, Bootes, Leo, and Corvus. It is best known by two remarkable stars: the first, Spica (α Virginis), a star of the first magnitude, is in the hand, which holds ears of corn, typical of the harvest, which approached in the time of the Greeks as the sun neared this star; the other, Prævindemiatrix, or Vindemiatrix (ε Virginis), took its name from the vintage. The star Spica forms a remarkable triangle with Arcturus and β Leonis (or Denebola); and of the bright stars in this triangle, Vindemiatrix is the one nearest to the line joining Arcturus and β Leonis.

The principal stars are as follows:—

Character. Not in Bayer. ( )	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
β	5	4002	3
η	15	4145	3
γ	29	4268	3
δ	43	4340	3
ε	47	4367	3
θ	51	4401	4
α	67	4480	1
ζ	79	4532	4
κ	98	4716	4
ι	99	4727	4
λ	100	4743	4
φ	105	4792	4
μ	107	4855	4
(z)	109	4878	4

Hesiod and Aratus unite in representing Virgo to be justice, who retired to heaven when the golden age came to an end: the former makes her the daughter of Jupiter and Themis; the latter, of Astræus and Aurora: others make her to be Fortune, others Ceres, &c.

VIRIDIC ACID. [Tannic Acid; *Viridic Acid.*]

VIRTUAL VELOCITIES. The name of the *principle of virtual velocities*, which is given to what is perhaps the most important generalisation in mechanics, is very ill-fitted to express the idea which is to be conveyed. It will take some space to prepare even the mathematical reader, unless he be already acquainted with the subject, for the reception of this principle as a real and physical consequence of the laws of matter. So long as it is only treated as a mathematical mode of expressing geometrical conditions, its import is hardly seen, and its value is lessened by a want of perfect conviction.

Our works on mechanics are now written in so very cold a style, and mathematical deduction has so completely taken the place of everything else, that little space is given even to interpretation of results, and none to illustration of first principles. The consequence is a strong leaning to purely mathematical definitions, which, though they place the student in the smallest possible time at the beginning of his career of deduction, nevertheless make it difficult for him ever to connect his first principles (first equations we ought rather to call them) with the actual properties of the matter around him, and with the phraseology which sight and touch make him feel to be justifiable. We do not like the system of mechanics in which velocity is only $ds : dt$, moving pressure but a name for $mdv : dt$, and the principle of virtual velocities nothing but a nickname for $\Sigma p dp = 0$. For a proper description of real facts, we would rather that nature should *abhor* a vacuum, that fluid should *try* to find its level, that the centre of gravity should *endeavour* to descend as low as possible, and so on. Of such language the mathematician must allow the use, if the learner be to feel the truth of the results of mechanics: and in no case is such permission of more importance than in the illustration of the principle before us.

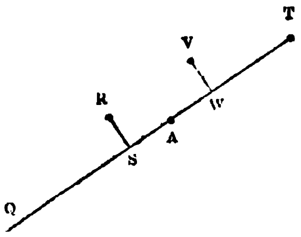
When we say that any system whatever is in equilibrium under the action of forces, it is obvious that the word equilibrium is only used for a state for rest, as opposed to one of motion; which last is possible to be imagined, and might actually take place, if it were not that the impressed forces mutually counteract each other's efforts. If a system could not move, if so many of its points were fixed that, consistently with those points remaining fixed, no geometrical possibility of motion was left, it would be useless to ask whether any given set of forces would keep that system in equilibrium or not. For the answer would be that the system must be in equilibrium, forces or no forces. But when it is left possible that a system may move, it then becomes a question whether a given set of forces will entirely prevent all motion, or will cause one of the possible motions to begin: and the alternative may be restricted by the use of as small a portion of time as we please. What will take place during the first millionth of a second after the forces are applied, rest or motion? And instead of the millionth of a second, any smaller fraction may be used; so that we may say the question of rest or motion, the settlement which of the two is to take place, may be considered as one which involves but an infinitely small portion of time. We shall throughout this article use the language of the infinitesimal calculus, leaving it to the reader to reduce it to the stricter form, if he think that there is such a thing.

Now all the different infinitely small motions of which it is possible that a system may take any one during the infinitely small time dt which elapses after forces are applied to it—are called *virtual* motions. This word is not used in the meaning which it commonly bears, as when we say that a man who does not prosecute a claim virtually (as good as) abandons it. When John Bernoulli used this adjective (and we can find none prior to him who did so) it was in a sense which it will not now bear: by a virtual velocity he meant any infinitely small velocity, or increase of velocity. But in modern times, virtual is used in the sense of potential, or possible: a virtual motion is one which a system might take, whether it take it or not: thus if forces keep a system at rest, it will not take any one whatsoever of the virtual (or possible) motions; but if they do not keep it at rest, it will, in the time dt which elapses after the forces are applied, take some one of the virtual motions, to the exclusion of the rest. Nevertheless, so long as it is geometrically possible that any one given motion might have taken place, we are at liberty to suppose that that motion has taken place (which is simply making an arbitrary displacement of the system), if by so doing, and noting the displacements which the different parts receive, we can draw any conclusions as to the conditions of equilibrium.

When we see a system in equilibrium, experience tells us that there are efforts at motion which are counteracted. Remove any one of the forces, or any part of one of them, and motion immediately begins. It is true that friction and other resistances prevent our having so good a perception of this truth as we otherwise might have; since, when equilibrating forces are removed in whole or in part, friction frequently supplies the place and maintains the equilibrium. A little reflection will however make it apparent that when a system is once in equilibrium, no addition nor subtraction of forces can be made without producing motion, unless the forces added or withdrawn be such as by themselves would maintain equilibrium.

A system, then, at rest, makes efforts to move, which efforts are counteracted; and the mathematical conditions of equilibrium, whatever they may be, must express that every force endeavours to produce motion; must contain, directly or indirectly, a measure of the energy of that force; and must show that a complete counteraction of all the efforts at motion takes place. But here arises a question, and one which is of the utmost importance in the comprehension of our principle. The number of virtual motions is usually infinite:—Does any given system of forces make an effort to produce every one of them, or some only? We know that, if the forces do not produce equilibrium, *one* of the virtual motions ensues in the first dt following the application of the forces, to the exclusion of all the rest; it ought not, therefore, to surprise the student if he were told that, for every given set of forces (a given system being always understood), some one motion prevented is every motion prevented. But in point of fact the direct contrary is true, in rigid systems at least: generally speaking, there is but one class of virtual motions which a given set of forces has no tendency to produce, and any one of the rest may be produced. Our meaning will appear in the following explanation:—We have seen [ROTATION] that every infinitely small motion of a rigid system may be produced by a screwlike motion,* namely, rotation round an axis, accompanied by a slipping up or down that axis. Take any line for an axis, and suppose a screw, fitted to its receiving screw (the latter immoveably fixed in space), to be described with that axis: suppose also that the system to which the forces are applied is fixed to the screw. Here then is every virtual motion prevented, except one; so that if the system begin to move, it must take that one motion. Now apply the given set of forces, and resolve them all in directions parallel to the axis, and in planes perpendicular to it. There must be motion unless the former forces destroy each other, and the latter have a resultant or resultants passing through the axis. Consequently, with certain exceptions (which, though infinite in number, are few compared with the rest), a given set of forces, acting on a given system, will produce any virtual motion, if others be excluded: but when there are various virtual motions not excluded, the system, if the forces do not balance one another, will take one in preference to any of the rest. The preceding argument ought to be more developed, but we have not room for such an explanation as would be intelligible to every one: most of the difficulty indeed lies in the purely geometrical conception of motion, and is foreign to our article.

We are to expect, then, as the condition of equilibrium, a collection of conditions, an infinite number, implying that, of an infinite number of motions, possible *à priori*, the given system of forces makes each *and* every one impossible. To make it appear in what the condition may probably consist, look at the following cases:—If one point of the system be fixed, forces applied at that point are useless, for they *only* produce a pressure or strain on the fixed point, and neither promote nor retard any virtual motion. If one point be restrained to move upon a given surface or curve, forces applied at that point perpendicular to that surface or curve are useless, for a similar reason. Thus suppose one point must be retained on a given horizontal plane: any weight added to that point has no effect on the equilibrium; it *is* merely equivalent to so much weight† laid upon the plane. Generally, then, a force produces no effect in equilibrium unless the point to which it is applied can move *in the direction of that force:* thus weight produces no effect when applied to a point of which all the virtual motions are horizontal. But let the plane be ever so little inclined to the horizon, a point restricted to move upon it has somewhat of vertical motion: weight applied at that point will have some effect in equilibrium. It would be natural to conclude (and let it be remembered that in these *à priori* views we are only stating strong probabilities) that the more freely a point may move in the direction of the force which acts upon it, the greater the effect of that force in producing or disturbing equilibrium. Now since it is sufficiently evident that, *cæteris paribus*, a force has more or less effect in proportion to its magnitude, for instance, that, under given circumstances, two pounds of pressure produce twice the effect of one pound, it seems that for any given virtual motion, the effect of each force varies jointly as the magnitude of the force, and the length over which, in that virtual motion, the point of application moves in the direction of the force. That is, suppose A to be the point of application of the force, and A Q to represent its direction and magnitude. In one virtual or possible motion of the system, let A be transferred to R, infinitely near to A. Draw R S perpendicular upon Q A, then A S is the space moved over in the direction of the force; and if the force contain P units of pressure, P × A S is the product on the value of which the efficiency of the force seems to have some dependence. Here, however, the motion A S is in



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* Simple translation is the extreme case in which the thread of the screw becomes parallel to the axis; and simple rotation the other extreme case in which the successive coils of the thread coincide.

† Here again the common ideas derived from friction must be abandoned; a weight attached to such a point might help, by the friction on the plane, to equilibrate the system.

the direction of the force, and the force helps to produce that motion; for it is obviously easier, *cæteris paribus*, that the point A should move in the direction A R, when the force acts in the direction A Q, than it would have been if the same force had acted in the opposite direction A T. But suppose that another virtual motion might bring A to V. Draw V W perpendicular to A T; then A W is the space moved over in the direction of the force, and P × A W is the product on which the efficiency of the force seems to depend. But here the motion A W is in the direction opposite to that of the force, and it is obviously less easy that the point A should move in the direction A V, when the force acts in the direction A Q, than it would have been if the force had acted in the opposite direction A T. Hence, to what has preceded, we may probably add that the efficiency of a force, in promoting or preventing one given kind of virtual motion, is to be considered as of one kind or another according, as, for that motion, the virtual motion of the point of application, estimated in the line of action of the force, is with the direction of the force, or opposite to it.

These conjectures, for they are nothing more, will show of the principle of virtual velocities, the moment it is announced, that it is a highly reasonable and probable principle. It may be announced as follows:—Let the forces which are applied to a system, at different points, be P, Q, R, &c., each in an assigned direction. Let one of the virtual (that is, possible) motions which the system may undergo in the infinitely small time dt succeeding the moment of application of the forces, be supposed to be given, upon trial. Decompose the several motions of the points of application of the forces each into two, one in the line of the applied force, the other perpendicular to that line: let dp, dq, dr, &c., be the resolved motions in the lines of the forces, and let those be reckoned positive which are in the directions of the forces, and negative which are in the contrary directions. Then $Pdp + Qdq + Rdr +$ &c., is a quantity on which it depends whether the given virtual motion can actually take place or not. If $Pdp + Qdq + Rdr +$ &c., $= 0$, that motion cannot be the result of the applied forces: but if $Pdp + Qdq + Rdr +$ &c. be not $= 0$, that motion *may* take place. And there is equilibrium, that is, no one of the possible motions can actually take place when $Pdp + Qdq + Rdr +$ &c. is always $= 0$, for every virtual motion; and there is not equilibrium when one or more virtual motions can be assigned, for which $Pdp + Qdq + Rdr +$ &c. is not $= 0$. This is the principle of *virtual velocities*, as to which perhaps the first thing that will strike the reader is that the word velocity does not occur in the explanation of it. But if we suppose the virtual motion of the system to be actually performed in the time dt, then the velocities of the points of application, in the directions of the several forces, are $dp : dt$, $dq : dt$, $dr : dt$, &c., and the principle above stated may be affirmed of

$$P\frac{dp}{dt} + Q\frac{dq}{dt} + R\frac{dr}{dt} + \text{\&c.}$$

instead of $Pdp + Qdq + Rdr +$ &c. But the latter is the more convenient of the two. The product Pdp is called the *moment* of the force P, which is not a well-chosen term, since "moment" is used in other senses. It would be much better (though we shall not here depart from established usage) that Pdp should be called the measure of the equilibrating power of the force P, or, in one word, the *power*[*] of the force P: with reference, of course, to the promotion or hindrance of those virtual motions only, in which dp is the part of the motion which is in the line of P's action. No perfectly general proof of this principle has been given; indeed to apply it demonstratively to the cases of fluid and gaseous systems would require a knowledge of the constituent parts of matter, and of their connection with each other, which we do not possess. But the cases in which it can be strictly shown are very extensive: all cases whatsoever in which the conditions of equilibrium can be established admit of the truth of this principle being shown *à posteriori*, with certain exceptions, the reasons of which will presently appear; and when it is assumed, it always leads to results which are consistent with the other known principles of mechanics. In the demonstration which we give, we shall confine ourselves to the case of forces which act upon points, which are either independent of each other, or some or all of which are connected by rigid rods without weight: and our limits require us to speak but briefly of all the steps which are purely mathematical. Ordinary works on mechanics give the simple illustrations which the beginner wants: and it is impossible to read anything like a general demonstration without being well acquainted with the infinitesimal calculus and with the principal formulæ of algebraic geometry of three dimensions.

First, let there be a single point A, the co-ordinates of which are x, y, and z. Let there act upon this point the forces P, in a direction which makes with the axes, angles α, β, γ; P′, the direction of which makes angles α', β', γ'; P″, the direction of which makes angles α'', β'', γ'', &c. Let the point A move to B, the co-ordinates of which are $x + dx$, $y + dy$, $z + dz$, and let A B make the angles λ, μ, ν with the axes. Then,

$$AB = \sqrt{(dx^2 + dy^2 + dz^2)},$$

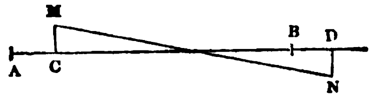
$$\cos\lambda = \frac{dx}{AB},\ \cos\mu = \frac{dy}{AB},\ \cos\nu = \frac{dz}{AB}.$$

Now the line A B decomposed in the direction of P, gives A B × cos (angle made by P with A B) or

$$AB\,(\cos\lambda\,.\,\cos\alpha + \cos\mu\,.\,\cos\beta + \cos\nu\,.\,\cos\gamma)$$
$$\text{or}\ \cos\alpha\,.\,dx + \cos\beta\,.\,dy + \cos\gamma\,.\,dz = dp.$$

Hence the moment of the force P is $P\cos\alpha\,.\,dx + P\cos\beta\,.\,dy + P\cos\gamma\,.\,dz$, and the sum of the moments of all the forces is $dx\,\Sigma\,(P\cos\alpha) + dy\,\Sigma\,(P\cos\beta) + dz\,\Sigma\,(P\cos\gamma)$, where $\Sigma\,(P\cos\alpha)$ stands for $P\cos\alpha + P'\cos\alpha' +$ &c., and so on. But when there is equilibrium $\Sigma\,(P\cos\alpha) = 0$, since $P\cos\alpha$, $P'\cos\alpha'$, &c., are the components of the several forces in the direction of x. For similar reasons $\Sigma\,(P\cos\beta) = 0$, $\Sigma\,(P\cos\gamma) = 0$, whence $Pdp + P'dp' +$ &c., is $= 0$ for every motion of which the point is capable.

Let there be any number of points, and let each of them be acted upon by any number of forces: but as all the forces which act upon a given point may be reduced to one, let R_1 be the force which acts on the first, and α_1, β_1, γ_1, be the angles it makes with the axes: let R_2, α_2, β_2, γ_2, stand in the same relations to the second point; and so on. Let x_1, y_1, z_1, be the co-ordinates of the first point, and so on. Let any of the points be connected by rigid bars without weight: and suppose A to be one of the points, and A B the bar connecting it with another point B. The point A, then, besides other forces, is acted on by a pressure called the tension of the bar, either in the direction A B or B A: while B, besides the other forces, is acted on by the same tension, but in a contrary direction. Supposing A B to receive one of its virtual motions, and to come into the position M N (which need not be in the same plane with A B), then if M C and N D be drawn perpendicular to A B, and if the position M N be infinitely near to A B, so that M C and N D need not be distinguished (so far as small quantities of the first order are concerned) from arcs of circles with the centres B and A—it follows that A C may be considered as the diminution of the line if A only changed place, and came to M, while B D may be considered as the quantity by which it would be lengthened, if B only changed place, and came to N. Hence, since the bar remains of the same length, we have A C = B D, or at least the two only differ by an infinitely small part of either. But A C gives the virtual velocity of the tension at A, and B D that of the tension at B, and these lines being equal, and the tensions equal, their moments are equal; but these moments have different signs, one of the virtual velocities being in the direction of its force, and the other in the opposite direction. Hence the sum of these two moments is $= 0$; and the same follows for the two moments of any other of the tensions, exerted by any other of the connecting bars. Let T_1 be the sum of the moments of the tensions which act on the first point, T_2, T_3, &c., of those which act on the second, third, &c., points; then, taking the principle as established above, for each point separately, we have $R_1\,dr_1 + T_1 = 0$, $R_2\,dr_2 + T_2 = 0$, &c.; by summing which we have $R_1\,dr_1 + R_2\,dr_2 +$ &c., $+ T_1 + T_2 +$ &c. $= 0$. But $T_1 + T_2 +$ &c. $= 0$; for, as shown, every term in each of T_1, T_2, &c., finds an equal and contrary term in one of the others. Hence $R_1\,dr_1 + R_2\,dr_2 +$ &c. $= 0$, or the principle is established for any system consisting of forces applied to points connected by rigid bars, and this whether there be connections enough to ensure complete stability of form or not.



Various other cases may be examined in which the same conclusion as the last will be arrived at, namely, that the principle of virtual velocities is true of the external forces only, and that those which arise from the internal forces of the system may be neglected. If, for example, one of the points to which a force is applied slide upon a string, in the manner of a bead, the ends of the string being attached to other points of the system, the two tensions are the same on both sides of the bead, and any virtual motion of the bead alone shortens one part of the string as much as it lengthens the other. Those parts, by which one side is lengthened and the other shortened, are, when the motion is infinitely small, the spaces from which the virtual velocities of the tensions are obtained, and they are of contrary signs. The moments of the tensions are therefore equal and contrary; or the principle is true independently of those tensions. Again, suppose one of the points of the system is restrained to move upon a given surface or curve; being tied in such a manner as to slip freely upon the surface or curve, without being able to leave it. The force which retains the point thus attached is perpendicular to the surface or curve, but every virtual motion of that point is (when infinitely small) in the tangent plane of the surface or tangent of the curve: so that there is no component in the direction of the force, and the moment of the force vanishes.

When questions occur in which friction is an element, the principle of virtual velocities is not of very easy application. Even in the ordinary modes of solving such problems, the formulæ which must vanish when there is no friction, are not required to vanish, but must lie between certain positive and negative limits, depending on the friction. A similar change must be predicated of the sum of the moments of the impressed forces; but as even Lagrange does not appear to have thought the principle before us conveniently applicable to friction problems, we may well dispense with the consideration of them here. When elastic bodies are in question the principle can be applied, but only on condition that the elasticities of the several parts of the system are considered as external, not internal forces: an hypothesis rendered necessary by our ignorance of the molecular constitution which gives rise to elasticity. It may also be said that in its application to hydrostatics there are mathematical conventions (expressive, no doubt, of truths, but foreign to the mere enunciation of the principle) which represent our ignorance of the molecular constitution of a fluid. On this point we should recommend the student who has enough of mathematics to have recourse to the 'Mécanique Analytique' of Lagrange, the standard work on virtual velocities: the demonstrations, so called, given by all the elementary writers we know of (even Poisson, see his 'Mécanique,' vol. ii., p. 512, 2nd edition) are mere illustrations conducted upon the most limited suppositions. These are more than excusable, considered with reference to the supposed mathematical knowledge of the reader; but it is not right to make him believe that he is considering a subject generally, when nothing but a limited case is presented to him. The great fault of the mathematical writers of our day is the *want of avowal of incompleteness:* and any one who looks in Poisson's table of contents for 'Démonstration du Principe des Vitesses Virtuelles dans l'Equilibre d'un Liquide,' and compares it with the article indicated, will see a notable instance.

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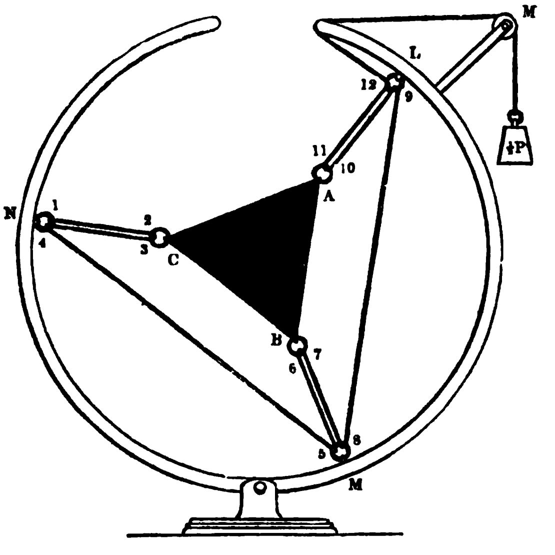
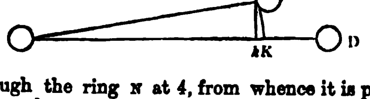
[*] Either of the words activity, efficiency, energy, would do as well; anything but *moment*, which has other meanings.

When we look at the preceding demonstration of the principle, we see that it depends upon knowledge of the mode of compounding and decomposing forces; but there is an *à priori* proof of a most singular character, as extensive as can be given by the mode already used. This proof was prefixed by Lagrange to the 'Mécanique Analytique,' and judging from the slight degree of notice which it has obtained from succeeding writers on mechanics, we should suppose that it was disputed or thought unsound. We have ourselves strong objections to the form given by Lagrange; but we believe that a sound and sufficient method of proof does exist in the principle which he has used; and this we shall endeavour to develope.

Suppose, first, that all the forces which are applied are equal to one another; the case of unequal forces will follow very readily. As an instance, suppose three equal forces applied at the points A, B, C, in the directions AL, BM, CN; ABC being a solid triangle without weight. At A, B, C, attach rings* to the triangular system, and at L, M, N, attach rings to a solid frame unconnected with the system, except by the flexible string now to be mentioned. Let this string be made fast to the ring N at 1, from whence let it be carried through the ring C, and again through the ring N at 4, from whence it is passed through M at 5; being nowhere attached to the frame except at 1. Its course is then denoted by the numbers 1, 2, 3, 4, &c.; and, when it emerges at 14, let a weight be attached, equal to the half of the force which is required to act at each of the points A, B, C; this force being P, the weight is $\frac{1}{2}$P. The tension of the string being everywhere the same, it is everywhere equal to $\frac{1}{2}$P: and at the point A each of the parts of the string (10, 9), and (11, 12), applies a force equal to $\frac{1}{2}$P, so that the force P is, from the two strings, applied at A. The same may be said of the points B and C. If then, at the outset, the system ABC were so placed that forces P, P, P, applied at the three points in the given directions would produce equilibrium, it follows that there will be no motion when the weight $\frac{1}{2}$P is made to act on the string; for equilibrating forces will at that instant be applied to the system: and the weight $\frac{1}{2}$P cannot move unless the triangle move.





Now it is obvious *à priori* that if any forces keep a system in equilibrium, forces exactly opposite to those forces will also keep it in equilibrium: if P, Q, R, keep a system in equilibrium: so will −P, −Q, and −R, forces equal and opposite to the first three. For it is obvious that all the six, P, −P, Q, −Q, R, −R, keep it in equilibrium, being three sets of equilibrating forces. Take away the set P, Q, R, which, by hypothesis, equilibrate the system, and the remaining set, −P, −Q, −R, will then equilibrate it. But here it must be noticed that when the inversion of directions is made, the inversion of the tensions must also be possible: a force which before the inversion pulls by a string, must, after the inversion, be supposed to push that string: that is to say, the string must have the property of a rigid bar as to pushing or pulling being indifferent. The reader of theoretical mechanics must accustom himself to the idea of a string which, though laterally flexible, can transmit a push or thrust in the direction of its length. Imagine the direction* of gravity to be changed in the machine, so that $\frac{1}{2}$P acts upwards, the string being capable of transmitting the thrust through the whole of its length. Nothing is then changed except the directions of the forces acting at A, B, C, in such manner that, if the original position be one of equilibrium, the weight $\frac{1}{2}$P cannot ascend, any more than it could descend in the first supposition.

When there is equilibrium, then, the weight $\frac{1}{2}$P, whether *it* be supposed to pull downwards or thrust upwards, cannot either ascend or descend. But what is to hinder $\frac{1}{2}$P from descending in the first case, or ascending in the second? The weight is only counterbalanced at 1, which is made fast to the ring at N, and if more string can be drawn out beyond (13) by the descent of $\frac{1}{2}$P, or pushed in by its ascent, there is no mechanical reason why such drawing out or pushing in should not take place. The reason why the ascent or descent cannot take place must be of a geometrical character, and Lagrange reasons as follows:—It will be sufficient that any infinitely small displacement of the triangle ABC should produce no displacement of the weight; and this will also be necessary: for if any possible infinitely small displacement of the system could let out string and give motion to the weight, the tendency of the weight to descend would produce that small displacement. But (implies Lagrange) it is enough that any infinitely small displacement of the system should only produce a displacement of the weight which is of an inferior order: or it is enough that the second displacement should be an infinitely small part of the first. Here we cannot follow the reasoning: why should the weight not be capable of descending because the first infinitely small motion of ABC is attended by one of an inferior order in the weight $\frac{1}{2}$P? We could name any number of cases in which continued motions begin in this manner. We can only understand Lagrange's argument to this extent: if there be a position of equilibrium at all, it must be that in which a given infinitely small displacement produces the smallest effect upon the weight; so that, if there be one position in which every displacement produces relatively an infinitely small displacement of the weight, that position, or none, must be the position of equilibrium. We shall, however, proceed with Lagrange's reasoning, and shall then endeavour to show that it may be saved from the preceding objection at least, if not rendered absolutely rigorous. Let S be the fixed ring to which D (moveable with the system) belongs; and let the latter, in a certain infinitely small displacement of the system, be removed to E. If SD be greater than SE, the string SD is shortened by the removal, and drawing the arc EK and the perpendicular Ek, the virtual velocity of the force acting in the direction DS is kD (and is positive), while the quantity by which each string is shortened is KD; but if SE be longer than SD, the virtual velocity is negative, and the string is lengthened. Hence, if α, β, γ, be the virtual velocities of the forces in their own directions, the expression $2\alpha + 2\beta + 2\gamma$ is, if positive, the quantity of string let out by the displacement; if negative, the quantity taken in. Or rather we should say that $2\alpha + 2\beta + 2\gamma$ differs from the quantity let out or taken in by an infinitely small quantity of the second order; for kD and KD, even when E is infinitely near to D, are not equal, but differ by a small quantity of the second order. Lagrange, then, confounding an infinitely small quantity of the second order with absolute *nothing*, compared with one of the first order, takes $2\alpha + 2\beta + 2\gamma = 0$, or, multiplying by $\frac{1}{2}$P, $P\alpha + P\beta + P\gamma = 0$, as the condition that an infinitely small displacement of the system will allow no displacement whatever of the weight; from which, by the aid of the mathematical consideration already alluded to, he completes what he gives as the proof that $P\alpha + P\beta + P\gamma = 0$ is the condition of equilibrium: which is for this case the enunciation of the principle of virtual velocities.

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* Pulleys, in Lagrange; but the wheel in the pulley is only a friction-wheel, and, as we are at liberty to dispense with friction in our thoughts, we may also deprive the pulley of its wheel.

* Lagrange avoids this second case by an appeal to mathematics, which not only destroys the elementary character of the proof, but is of a character incongruous with the other parts of it, and is moreover not always correct.

Before proceeding to give our view of the manner in which this proof may be amended, we shall point out how to proceed when the forces are not equal. In such case they are either commensurable or incommensurable: let them be commensurable, and let them be $l\text{P}$, $m\text{P}$, $n\text{P}$, where l, m, n, are integers. Instead of passing the string twice only through each ring, pass it $2n$ times through C and N, $2m$ times through B and M, $2l$ times through A and L. Then, the instant the weight $\frac{1}{2}\text{P}$ is applied, there are $2l$ strings in the direction AL, each with the tension $\frac{1}{2}\text{P}$, or altogether there is the force $l\text{P}$, applied to A in the direction AL; and similarly of the rest. If, then, α, β, γ, be as before, we have $2l\alpha+2m\beta+2n\gamma$, differing only by an infinitely small quantity of the second order from the quantity of string let out or taken in by an infinitely small displacement of the system. The usual methods apply for the extension of this reasoning to the case in which the forces are incommensurable.

Let $\text{AL}=a$, $\text{BM}=b$, $\text{CN}=c$: then the whole length of the string as far ab (13) is $2la+2mb+2nc+$ a constant made up of (4, 5), (8, 9), and (12, 13). Hence $2lda+2mdb+2ndc$ is the infinitely small quantity taken in or let out by an infinitely small displacement; taken in when positive, let out when negative; so that da, db, dc, answer to $-\alpha$, $-\beta$, $-\gamma$, in the preceding. Now

1. It is established that, equilibrium existing, equilibrium will remain when all the forces take opposite directions.

2. Neither a, b, c, nor their differential coefficients, can become infinite in any position of the system; so that the only way in which $2la+2mb+2nc$ can become a maximum or a minimum is by $2lda+2mdb+2ndc$ becoming, in the language of the differential calculus, *nothing*, that is, more strictly, an infinitely small quantity of the second order.

Now let the weight $\frac{1}{2}\text{P}$ act *downwards*, and let it draw out all the string possible, and then rest. There must then be equilibrium, for every displacement makes the weight rise; and the weight has no tendency to take advantage, so to speak, of this power of rising. Consequently, there must be equilibrium when $2la+2mb+2nc$ is a minimum, the weight acting downwards; that is, when $2lda+2mdb+2ndc$ is always positive, and of the second order; or when $\text{P}l.\alpha+\text{P}m.\beta+\text{P}n.\gamma$ is always negative, and of the second order. And this equilibrium is stable; for any displacement makes the weight rise, and its tendency is to descend, and restore the former state. Now reverse the direction of the weight, and let the string communicate thrust instead of pull, as before described. Then there is still equilibrium (which is demonstrable independently) because only the directions of the forces are changed; but since the forces change direction, the virtual velocities change sign, and $\text{P}l.\alpha+$, &c., is always positive, and of the second order. Here, then, though the weight (we call $\frac{1}{2}\text{P}$ *weight* always, whether it tend upwards or downwards) tends to rise, and (geometrically speaking) can rise, it does not rise: observe, also, that the rise would be an infinitely small quantity of the second order. The equilibrium in this case is unstable, for every displacement raises the weight, which does not tend to return. Now let the weight $\frac{1}{2}\text{P}$ act *upwards*, and let it push in all the string possible, and then rest. There must then be equilibrium, for every displacement makes the weight fall, and the weight has no tendency to take advantage of this power of falling. Consequently, there must be equilibrium when $2la+$, &c. is a maximum, the weight acting upwards; that is, when $2lda+$, &c. is always negative, and of the second order; or when $\text{P}l.\alpha+$, &c. is always negative,[*] and of the second order; and this equilibrium is stable, for any displacement makes the weight fall, and its tendency is to rise and restore the former state. Now reverse the direction of the weight, and let the string pull, instead of thrust. There is still equilibrium (because only the directions of the forces are changed): the virtual velocities change sign, and $\text{P}l.\alpha+$, &c. is always positive, and of the second order; and in this last case, though the weight tends to fall, and (geometrically speaking) can fall, it does not fall. Observe, also, that the fall would be an infinitely small quantity of the second order; and the equilibrium in this case is unstable, for every displacement lowers the weight, which does not tend to return.

Collecting these cases, it appears then that whenever $\text{P}l.\alpha+$, &c. is, for every infinitely small displacement, an infinitely small quantity of one given sign, there is equilibrium; stable when that sign is negative, unstable when it is positive. But supposing $\text{P}l.\alpha+$, &c. to be of the second order, sometimes of one sign, and sometimes of the other, according to the displacement, the preceding reasoning does not apply. Nor do we see how it can be applied without the assumption that an equilibrium, which is produced, though all the displacements of the weight favour the motion which it tends to take, is *à fortiori* produced when some only do the same. Taking the case in which the weight acts downwards, we have seen that there is equilibrium when the descent of the weight is of the second order, and *always* downwards; the circumstance of the descent being of the second order, produces equilibrium, even though its direction is that which the weight can take. Still more must there be equilibrium when all the descents are of the second order at least, and some only downwards.

Hence, in every case, $\text{P}l.\alpha+$, &c. $=0$ (in the common language of the differential calculus) gives a position of equilibrium; and we have now to prove the converse, namely, that every position of equilibrium gives $\text{P}l.\alpha+$, &c. $=0$ (Lagrange proves this converse first). This converse can be proved, we submit, without taking it for granted, at once, with Lagrange, that if any motion of $\frac{1}{2}\text{P}$ of the first order were possible, the weight would, by its tendency to descend, take that motion.[*]

Supposing the system to be at rest, and the weight to act downwards, it is obviously physically possible that a given finite velocity should be communicated to the weight. Suppose a blow to be given to the weight in a downward direction, such as would communicate a finite velocity; what would be the effect upon the system at the instant when the weight receives the blow downwards? An impulsive strain upon the string, which would only communicate forces proportional to those already existing,[†] and could not disturb the equilibrium. The system then cannot move, neither therefore can the weight move. Now as it is unquestionably physically possible that the weight may take a finite velocity, the impossibility of moving the system must be geometrical; or a velocity communicated to the system must, be it what it may at the first instant, communicate none to the weight; and the definition of velocity shows that this can only happen when, the displacements of the system in the time dt bearing a finite ratio to dt, that of the weight is infinitely small compared with dt; that is, when the displacement of the weight is infinitely small compared with those of the system. From this it follows that $2l\alpha+$, &c. is infinitely small as compared with a, &c.

We do not know how to make the preceding prove its converse, and we object to the mode pursued by Lagrange. Having proved that equilibrium gives $2l\alpha+$, &c., that is, having proved it on the distinct assumption that the weight cannot descend in the first instant through a quantity comparable to a, &c., he then proceeds as follows:—Reciprocally $2l\alpha+$, &c. $=0$, gives a case of equilibrium; for "the weight remaining immoveable under all displacements, the powers which act upon the system remain in the same state, and there is no more reason why they should produce one of the two displacements than the other, of any two in which α, &c. have contrary signs. It is the case of the balance which remains in equilibrium, because there is no more reason why it should incline on one side than the other." Now, first, this reasoning might just as well be applied to prove equilibrium when $2l\alpha+$, &c. is *not* $=0$; secondly, it is not the case of the balanced lever of Archimedes, for there is not that same symmetry, either geometrical or mechanical, which makes it impossible to admit either motion in preference to the other [STATICS; SUFFICIENT REASON]; thirdly, there is a mechanical reason why one of the motions should be taken rather than the other, namely, that one in which the displacement of the weight (even though supposed of the second order) is positive. This last will appear sufficiently in the sequel.

We shall now proceed to show that the moment the principle of virtual velocities is granted, a problem of statics becomes one of pure mathematics. This is all we can undertake to illustrate; and for this purpose any mathematical result may be taken for granted. First, let the force P be decomposed into three, X, Y, Z, in the direction of x, y, and z; and let the point of application move until the co-ordinates are $x+dx$, $y+dy$, $z+dz$. Then a force equal and opposite to P (of which the moment is $-\text{P}dp$) balances X, Y, and Z; so that the principle gives $\text{X}dx+\text{Y}dy+\text{Z}dz+(-\text{P}dp)=0$, or $\text{P}dp=\text{X}dx+\text{Y}dy+\text{Z}dz$. Do the same with each of the forces, and we have $\Sigma(\text{P}dp)=\Sigma(\text{X}dx)+\Sigma(\text{Y}dy)+\Sigma(\text{Z}dz)$. If the system be rigid, every virtual motion may be decomposed into two: a motion of translation of any one given point, and a motion of rotation round an axis passing through that point. Let x_0, y_0, z_0, be the co-ordinates of any point which moves with the system, and let this point move so that its co-ordinates shall become x_0+dx_0, y_0+dy_0, z_0+dz_0, at the same time that the system revolves through an angle $d\phi$ about an axis passing through the point (x_0, y_0, z_0), and making angles λ, μ, ν with the three axes. If the consequence of this motion be that the point whose co-ordinates are x, y, z, moves so that its co-ordinates become $x+dx$, $y+dy$, $z+dz$, we have

$$dx=dx_0+\left\{\cos\mu\,(z-z_0)-\cos\nu\,(y-y_0)\right\}d\phi$$
$$dy=dy_0+\left\{\cos\nu\,(x-x_0)-\cos\lambda\,(z-z_0)\right\}d\phi$$
$$dz=dz_0+\left\{\cos\lambda\,(y-y_0)-\cos\mu\,(x-x_0)\right\}d\phi$$

from which we find for

$$\Sigma(\text{P}dp) \text{ or } \Sigma(\text{X}dx)+\Sigma(\text{Y}dy)+\Sigma(\text{Z}dz),$$

the following expression:—

$$\begin{aligned}&\Sigma\text{X}\,.\,dx_0+(z_0\Sigma\text{Y}-y_0\Sigma\text{Z})\cos\lambda\,d\phi+\Sigma(\text{Z}y-\text{Y}z)\,.\cos\lambda\,d\phi\\&+\Sigma\text{Y}\,.\,dy_0+(x_0\Sigma\text{Z}-z_0\Sigma\text{X})\cos\mu\,d\phi+\Sigma(\text{X}z-\text{Z}x)\,.\cos\mu\,d\phi\\&+\Sigma\text{Z}\,.\,dz_0+(y_0\Sigma\text{X}-x_0\Sigma\text{Y})\cos\nu\,d\phi+\Sigma(\text{Y}x-\text{X}y)\,.\cos\nu\,d\phi\end{aligned}$$

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[*] When the action of the string is that of a thrust, it will be seen that da is $=\alpha$, &c., since the virtual velocities change sign.

[*] It seems to us just as sound to say that if there be any motion of the second order possible, the weight will take that motion, and in an infinitely small time acquire a velocity of the first order, which is exactly what takes place in a body falling freely from rest.

[†] It is here assumed that whatever forces keep a system at rest, impulses proportional to those forces, and applied in the same manner, will not disturb the equilibrium.

and in the case of equilibrium this is always = 0. Since dx_0, dy_0, dz_0, cos $\lambda d\phi$, cos $\mu d\phi$, cos $\nu d\phi$, can each receive any value we please independently of the rest, the preceding can only vanish when the six following conditions are fulfilled:—

$$\Sigma\mathrm{X} = 0 \qquad \Sigma\mathrm{Y} = 0 \qquad \Sigma\mathrm{Z} = 0$$
$$\Sigma(\mathrm{Z}y - \mathrm{Y}z) = 0 \qquad \Sigma(\mathrm{X}z - \mathrm{Z}x) = 0 \qquad \Sigma(\mathrm{Y}x - \mathrm{X}y) = 0$$

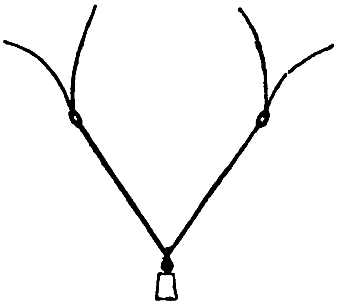
which are the six well-known equations of equilibrium of a rigid system.

We might give more examples, but our limits require us at once to enter upon a point which will require fuller explanation, because the student will not find it in any elementary work. "When $\Sigma(\mathrm{P}dp)$ is = 0 for every virtual motion, there must be equilibrium:" but the converse, namely, that "when there is equilibrium the equation $\Sigma(\mathrm{P}dp) = 0$ must be true for every virtual motion," has not the same universality as the direct proposition. If we look carefully at the proof, we shall see that, taking any particular instance of virtual motion, the only reason why we want $\Sigma(\mathrm{P}dp)$ to be = 0 for that particular motion, is, that the forces may not be able to make the system set off with that motion: or that the incapability might exist even though that motion were the only one which the system could take. If then there be in the nature of the system itself any reason why a particular case of virtual motion should be unattainable by the action of those forces, we have no longer any reason to say that $\Sigma(\mathrm{P}dp)$ must be = 0 in that case.

As a general rule, if P, Q, R, &c. be the acting forces, and $\mathrm{P}dp + \mathrm{Q}dq + \mathrm{R}dr +$ &c., the sum of their moments; and if in one virtual motion $dp = \alpha$, $dq = \beta$, $dr = \gamma$, &c., that one virtual motion has its opposite, in which $dp = -\alpha$, $dq = -\beta$, $dr = -\gamma$, &c. And we shall presently see that if that one motion and its opposite be by proper restrictions made the only ones which the system can take, the system will begin to take the first motion if $\mathrm{P}\alpha + \mathrm{Q}\beta + \mathrm{R}\gamma +$ &c. be positive, and the opposite if $\mathrm{P}(-\alpha) + \mathrm{Q}(-\beta) + \mathrm{R}(-\gamma) +$ &c. be positive. In fact, a system must set off from rest in such manner that the sum of the initial moments is positive: and it is clear enough that either $\mathrm{P}\alpha +$ &c., or $\mathrm{P}(-\alpha) +$ &c. must be positive unless both vanish. As a general rule then, $\mathrm{P}\alpha +$ &c. must vanish; for if not, either the virtual motion first named, or its opposite, has a positive sum of moments, and can be, and (if no other motion can take place) will be, an initial motion of the system. But if ever it should happen that there are cases in which a virtual motion is possible, but its opposite motion is impossible, then all that is requisite is that for the possible one of the pair, $\Sigma\mathrm{P}dp$ should be 0 or negative, *not positive*. There is another exception of a remarkable character, for which it will be better to wait until we come to see the meaning of the sum of the moments in a dynamical point of view. Excluding this for the present, let a virtual motion which has its opposite be called a double motion, and one which has not its opposite, a single motion: then the true statement of the principle of virtual velocities is as follows:—

If $\Sigma\mathrm{P}dp$ be nothing for every double virtual motion, and nothing or negative for every single one, there is equilibrium: and if there be equilibrium, then $\Sigma(\mathrm{P}dp)$ is nothing for every double virtual motion, and nothing or negative for every single one.

We might easily have incorporated the consideration of these exceptional cases of single virtual motions in the general proof. We shall now give a simple instance. Let a weight be fastened to the middle of a string, at the end of which are two rings; these rings slide upon curves which have cusps as in the diagram. The weight is in equilibrium, and the weight is the only external acting force: but its moment is not nothing (that is, is not of the second order with reference to the displacement of the rings), but is negative. The virtual motions of the rings are single, and can only be upwards. The reader who compares the preceding omission in the statement of the principle of virtual velocities with VARIATIONS, CALCULUS OF, will see a remarkable likeness between the cases: in fact, these errors and several others depend upon the same sort of omission, which may be stated as follows:—If there be a proposition (A) which is true on condition that the quantity B is never positive; and if, generally speaking, every negative value of B be accompanied by a corresponding positive one, then, generally speaking, (A) cannot be true if B be negative: that is, the truth of (A) requires B = 0. But if there be exceptional or singular cases in which negative values of B are *not* accompanied by corresponding positive ones, then B = 0 is no longer necessary; it is enough that B should be negative. Now the error which has run through the results of the differential calculus from book to book, from country to country, and from century to century, consists in taking the usual and general case for universal, and forgetting the exception.



The principle of virtual velocities is applied to dynamics by means of the celebrated principle which goes by the name of D'Alembert, propounded by him in his treatise on dynamics, published in 1743. We have touched upon this principle in FORCES, IMPRESSED AND EFFECTIVE, but we have referred the complete development of it to the present article.

It will do for our present purpose to suppose a system of points connected together, each point being considered as a certain mass of matter. Whatever may be the faults of the system of Cavalieri [CAVALIERI, in BIOG. DIV.] for geometrical deduction, it is sound enough mechanically considered: a point may not be taken to be one of the constituent parts of a length, but there is no difficulty in considering it as endowed with weight and impenetrability, or as rigidly connected with other points. If we imagine a mass of matter to be divided into an infinite number of infinitely small elements, each of which is an extended mass, though we may not, for geometrical purposes, suppose each of these elements to have its *bulk* collected in any one of its points, there is no difficulty in supposing its *mass* to be so collected. If then we begin with the consideration of a finite number of points, having various masses, we may, by increasing the number of our points and diminishing their masses, approach as near as we please to the case of a continuous geometrical solid, all the parts of which have weight, and of which the density varies according to any law. Again, when a system moves, and when the law of its motion is known, we can determine, at any one instant [VELOCITY], the velocity of any one point in any one direction, and the acceleration (or retardation, *negative* acceleration) at that one instant: that is to say, the rate per second at which the motion is receiving acceleration at the moment named. From this acceleration, as in the place last cited, we can determine the pressure which the mass of the point in question is actually experiencing at the moment; for on one mass there is but one pressure which can produce acceleration at one given rate. In this way then we can determine the pressures which the various points (or molecules*) of the system are undergoing; and this determination is made *in terms of the motion*, that is, in terms of the velocities and accelerations of the molecules, the pressures being derived from the accelerations by reference to the known masses of the molecules. The pressures so obtained are called *effective forces*, a sufficient and expressive name. But it by no means follows that the forces *applied* at the different molecules are those which are *effective* on those molecules. Two molecules are inseparably joined by a rigid bar without weight, and thrown into vacuous space. If these molecules were thrown separately, each would describe a parabola; but as the case stands, the centre of gravity of the molecules describes a parabola, and the bar revolves round its centre of gravity [TRANSLATION and ROTATION]: the effective forces are very different from the impressed forces. Now D'Alembert's principle is the expression of this simple law, that *force is never lost*† *nor gained*. If a force applied to any molecule of the system be not wholly effective on that molecule, the part which is not effective on the molecule of application is effective elsewhere; and if the motion gained by or rate of acceleration shown by any given molecule be greater than is due to the force impressed on that molecule, some other molecule of the system must have less than is due to its impressed force. Thus the motion of a system of connected molecules involves a collection of debtor and creditor accounts, the balances of which cannot show, when put together, the smallest amount of momentum in any direction, except what the system either had at the beginning or has received from the impressed forces during the motion. The consideration of the third law of motion [MOTION, LAWS OF,] would make such a result appear extremely probable, if not necessary; but a specific demonstration of the truth of the principle can be given.

Let the molecules have the masses m_1, m_2, &c., and let the impressed forces be such as, in their directions, would give the rates of acceleration P_1, P_2, &c., if these molecules were free and unconnected. Then [FORCE; MASS; VARIATION; VELOCITY] $m_1\mathrm{P}_1$, $m_2\mathrm{P}_2$, represent the pressures impressed, on the condition that the unit of pressure is that which produces a unit of acceleration in the unit of mass. Let the effective pressures, derived from the velocities in the directions of the co-ordinates of x, y, and z, and compounded into one force for each molecule, be such as would produce the rates of acceleration Q_1, Q_2, &c.; so that the effective pressures are $m_1\mathrm{Q}_1$, $m_2\mathrm{Q}_2$. &c. When two forces act on a point, either is equivalent to the other with a certain third force; let $m_1\mathrm{P}_1$ be equivalent to $m_1\mathrm{Q}_1$ and $m_1\mathrm{R}_1$; let $m_2\mathrm{P}_2$ be equivalent to $m_2\mathrm{Q}_2$ and $m_2\mathrm{R}_2$, and so on. Then the system (P) of impressed forces is equivalent to the system (Q) of effective forces, together with the system (R): for (P) substitute (Q) and (R), and the effect upon the system, in the infinitely small time following the moment of which we speak, is what it would have been if (P) had continued. But that effect is precisely what is produced by (Q); for (Q) was nothing but the pressures necessary to produce the actual effect of which we are speaking. Therefore (R) has no effect, and would of itself equilibrate the system: to suppose that (R) would not equilibrate, or would produce some motion, while (Q) is actually calculated to produce all that is to take place, is to suppose that the system will, in the infinitely small time next ensuing, have another motion besides that which (Q) would produce, which is absurd. Consequently (R) is a system of equilibrating forces, which is expressed by saying that the forces lost and gained balance one another: for if $m_1 P_1$, the force impressed on m_1, be equivalent to $m_1 Q_1$ and $m_1 R_1$, of which $m_1 Q_1$ is enough to produce what takes place, it is obvious that $m_1 R_1$, so far as the molecule m_1 is concerned, is lost. It would be better to say that $m_1 R_1$ is transferred, and that all the forces transferred balance one another. Again, since (R) is wholly without effect, it follows that (P) is equivalent to (Q); or, at every instant of the motion, the impressed forces are a set of equivalent statical powers with the effective forces: so that if either set were applied to the system at rest, and also the opposites of all the forces in the other set, there would be equilibrium. Or the impressed forces balance the effective forces with their signs changed. Now the effective forces on m_1, in the directions of x, y, and z, are $m_1 \frac{d^2x_1}{dt^2}, m \frac{d^2y_1}{dt^2}, m_1 \frac{d^2z_1}{dt^2}$, and similarly for the rest; while, if we decompose the rate of acceleration P_1, into X_1, Y_1, Z_1, in the directions of x, y, and z, the impressed pressures in these directions are $m_1 X_1, m_1 Y_1$, and $m_1 Z_1$. And [VARIATIONS, CALCULUS OF,] to distinguish the virtual motion which the problem of equilibrium requires, from the actually coming motion in terms of which the effective forces are expressed, we may use δx, instead of dx, in the former, and so on. Hence, changing the signs of the impressed forces and combining them, so changed, with the effective forces, we have, for the fundamental equation of every dynamical problem—

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* A molecule, in geometrical mechanics, means a point, endowed with the properties of a mass of matter, finite or infinitely small, as the case may be.

† We here exclude friction and resistances, but only on account of our ignorance of the action of these forces. The forces lost (that is, lost with respect to the system) are here communicated to other substances, to the mass in contact or to the air.

$$\Sigma\left(\frac{d^2x}{dt^2} - X\right) m\delta x + \Sigma\left(\frac{d^2y}{dt^2} - Y\right) m\delta y + \Sigma\left(\frac{d^2z}{dt^2} - Z\right) m\delta z = 0.$$

From which are obtained, as in a preceding process, the following six equations of motion, abbreviating $d^2x : dt^2$ into x'', and so on—

$$\begin{array}{ll} \Sigma(mx'') = \Sigma(mX) & \Sigma\{m(z''y - y''z)\} = \Sigma\{m(Zy - Yz)\} \\ \Sigma(my'') = \Sigma(mY) & \Sigma\{m(x''z - z''x)\} = \Sigma\{m(Xz - Zx)\} \\ \Sigma(mz'') = \Sigma(mZ) & \Sigma\{m(y''x - x''y)\} = \Sigma\{m(Yx - Xy)\} \end{array}$$

These equations express the property already mentioned [TRANSLATION], namely, that the centre of gravity moves as it would do if all the masses were collected there, and all the pressures applied there. We shall merely enumerate the steps of the proof of this proposition. The co-ordinates of the centre of gravity being x_0, y_0, z_0, we have $x_0 \Sigma m = \Sigma(mx)$, &c., whence $x_0'' \Sigma m = \Sigma(mx'') = \Sigma(mX)$, &c., which are precisely the equations for the motion of a molecule of the mass Σm, and to which the force $\Sigma(mX)$ is applied. With regard to the initial velocity which ought to be given to the centre of gravity when the molecules are there collected, observe that $x_0' = \Sigma(mx') \div \Sigma m = \left\{A + \Sigma\left(\int mX\,dt\right)\right\} \div \Sigma m$, where A is the initial value of $\Sigma(mx')$. Consequently, at the commencement of the motion x_0' should have the same value as $\Sigma(mx') \div \Sigma m)$, or we should have $x_0' \Sigma m = \Sigma(mx')$ at the outset; that is, the momentum of the collected mass, in the direction of x, should be the same as the sum of the momenta of the molecules in the system, and the same of the other co-ordinates. Again, let ξ, η, ζ, be the co-ordinates, referred to the centre of gravity, of the point whose original co-ordinates are x, y, z.

We have then $x = x_0 + \xi$, $y = y_0 + \eta$, $z = z_0 + \zeta$; also $\Sigma.m\xi = 0$, $\Sigma m\eta = 0$, $\Sigma m\zeta = 0$. Substitution gives

$$\begin{aligned} \Sigma\{m(z''y - y''z)\} &= y_0 \Sigma mZ - z_0 \Sigma mY + \Sigma\{m(\zeta''\eta - \eta''\zeta)\} \\ &= \Sigma\{mZ(y_0 + \eta) - mY(z_0 + \zeta)\} \end{aligned}$$

$$\text{whence } \Sigma\{m(\zeta''\eta - \eta''\zeta)\} = \Sigma\{m(Z\eta - Y\zeta)\}$$

which, with the two other equations similarly deduced, are precisely those which would determine the motion if the centre of gravity were fixed and the forces then applied. We must refer to works on the subject for further development of these conditions, and shall proceed to cases more illustrative of the principle under consideration.

Among the virtual motions, one of course is the motion the system is actually about to take. In this case δx is dx, &c., and the fundamental equation becomes

$$\Sigma\{m(x''dx + y''dy + z''dz)\} = \Sigma\{m(Xdx + Ydy + Zdz)\}.$$

Now the first side of this equation is nothing but the differential with respect to the time of $\frac{1}{2}\Sigma\{m(x'^2 + y'^2 + z'^2)\}$, or $\frac{1}{2}\Sigma mv^2$, v_1, v_2, &c., being the actual velocities of the molecules at the end of the time t. Hence we have

$$\Sigma mv^2 = A + \Sigma\left\{m\int(Xdx + Ydy + Zdz)\right\}$$

where A is the value of Σmv^2 at the commencement of the motion, and the integral also begins at that commencement. Suppose the system to be at rest at the commencement of the motion, then $A = 0$, since each of the incipient velocities is nothing; consequently at the end of the first infinitely small element dt, Σmv^2 has changed from 0 to $m(Xdx + Ydy + Zdz)$. But this is precisely the sum of the moments of the impressed forces in the principle of virtual velocities; and Σmv^2 being $m_1 v_1^2 + m_2 v_2^2 +$ &c., must be a positive quantity. Hence the sum of the moments must be positive, for the virtual motion which the system actually tends to take: and this is the principle of which we have forestalled the use in completing the correct enunciation of the principle of virtual velocities. This might be suspected beforehand from the following consideration:—The forces which have positive moments are those which tend, so far as they go, to produce the virtual motion in question; and those which have negative motions to hinder it. Whatever motion the system takes, it must be one in which the forces tending to produce that motion predominate over those which tend to hinder it: or the forces with positive moments must have those moments together larger than the forces with negative moments.

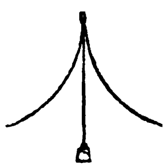
The choice which the system * makes among all the virtual motions, in which to begin its motion, is that in which the sum of all the moments of the forces is a maximum, in the sense which will presently be explained. Since every motion of a system can be reduced to a translation of the centre of gravity and rotation round an axis passing through that centre, let us reduce the virtual motion to terms of the motion of and round the centre of gravity. If ΣmX, &c., be P, Q, R, and if $\Sigma\{m(Zy - Yz)\}$ &c., be L, M, N, it follows from what has been shown respecting the motion of this centre that its first direction of translation (the system starting from rest) is such that dx_0, dy_0, dz_0 are in the proportion of P, Q, R, and that the axis round which the system begins to turn makes angles with the axes of x, y, and z, whose cosines are in the proportion of L, M, and N. Now suppose any motion of and round the centre of gravity, and returning to the expressions in which the sum of the moments is given in terms of those motions, observe that we must write mX for X, &c., because the pressures are now represented by mX, &c., which were then represented by X, &c. Moreover $z_0 \Sigma mY - y_0 \Sigma mZ$, and the other terms corresponding, all vanish, because $z_0 = \Sigma mz \div \Sigma m$, &c. We have then for the sum of the moments,

$$P dx_0 + Q dy_0 + R dz + (L \cos\lambda + M \cos\mu + N \cos\nu)\, d\phi.$$

Let the displacement of the centre of gravity be du, we have then $du = \sqrt{(dx_0^2 + dy_0^2 + dz_0^2)}$. Now the theorem is, that for given values of du and $d\phi$, for a given amount of translation and rotation, the direction of translation and the position of the axis of rotation, in the virtual motion which the initial effect of the forces actually causes, are such as to make the preceding expression a maximum.

First, it must be shown by the common methods that for a constant value of $p^2 + q^2 + r^2$, the expression $Ap + Bq + Cr$, *if then positive*, is a maximum when p, q, r are in the proportion of A, B, C. Now in the actual motion of the system, $P dx_0 + Q dy_0 + R dz_0$, and $(L \cos\lambda + \text{\&c.})\, d\phi$, *are positive quantities*; for the first is the initially obtained value of $\frac{1}{2}\Sigma mv^2$ when the system is all collected in the centre of gravity and all the forces are then applied: and the second is the same when the centre of gravity is fixed and the system begins to move about it. And since the variables of the first and second are entirely independent of each other, the sum of the two is a maximum when each separately is a maximum. In the first $dx_0^2 +$ &c., is a constant, being du^2, and therefore the first is a maximum when dx_0, dy_0, and dz_0 are in the proportion of P, Q, R. But in the second, $\cos^2\lambda + \cos^2\mu + \cos^2\nu = 1$, whence the second is a maximum when $\cos\lambda, \cos\mu, \cos\nu$ are in the proportion of L, M, N. But these two sets of conditions put together precisely represent the motion which at the outset the system does take from the impressed forces. Whence the theorem is true, as asserted.

We may now treat the exception of which we have spoken in a preceding part of this article. Suppose that the moments in all the directions in which the system can move are equal, or else that there is among them a set which are equal, and each of them greater than any of the rest. Which of all the virtual motions having these moments is the system to take? It cannot prefer either, and will remain in equilibrium. As an instance, let the end of a string be attached to a curve on which it can slide freely, while the string supports a weight. Let the curve have a cusp pointing upwards, with its tangent vertical, and let the end of the string be placed at the cusp, as



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* We confine ourselves here to a rigid system, though the proposition is true universally. But the universal proof would be too long.

in the diagram. There will be equilibrium, but the principle of virtual velocities will not be true, even in the extended form which we have used. The moments belonging to the two possible motions are positive, but they are equal. On which side is the descent to take place?

The mathematician has a warning in such cases, which may be easily and briefly expressed. The expression $\Sigma \mathrm{P}dp$, before it is used, requires that the quantities p_1, p_2, &c., should be reduced to the smallest number of independent variables. Let $q_1, q_2 \ldots$ be these variables, and let the sum of the moments, when reduced to terms of these variables, be $\mathrm{Q}_1 dq_1 +$ &c., or $\Sigma \mathrm{Q}dq$. The principle is then intelligible when, for all the virtual motions, dp_1, dq_1, &c., have finite ratios to one another. But if there be any position in which for a certain virtual motion one or more of the set dp_1, dp_2, &c., become infinite with respect to those of the set dq_1, dq_2, &c., the equation becomes incapable of being used. For if we take the actual virtual *velocities*, and attempt to reduce

$$\Sigma \mathrm{Q} \frac{dq}{dt} \text{ to its equivalent } \Sigma \mathrm{P} \frac{dp}{dt},$$

the first side, which may be made finite, is equated to an expression in which infinite terms occur, which is always a warning to expect the possibility of cases of exception. Circumstances of this sort have never received sufficient investigation, and in all probability there are numerous varieties of the cases of equilibrium which arise out of them, and which cannot be treated by the ordinary principle. So much we may certainly say, that if there be different virtual motions with the sums of the moments positive and maxima, either there must be equilibrium, or the test for determining which of the motions will ensue is wholly unknown.

On the history* of virtual velocities, there is not much to say. Guido Ubaldi saw it in some cases, Galileo in some others; Wallis adopted it as a principle, and after him John Bernoulli, who gave it in the most general form. Lagrange made it the foundation of his 'Mécanique Analytique,' and since his time it has formed part of every well-constituted treatise on mechanics. It was in the 'Mécanique Analytique' that the principle given by D'Alembert was first joined to that of virtual velocities in such a manner as to give the science of dynamics its present uniformity of system.

VIS INERTIÆ. [Inertia.]

VIS VIVA, or *living force*, a name given in mechanics to the following index of the state of a system in motion:—the sum of all the masses, each multiplied by the square of its velocity. If the system be considered as composed of a finite number of molecules, the vis viva may be expressed by the symbol Σmv^2; but if it be a continuous mass, or a collection of continuous masses, by $\int v^2 dm$, or $\Sigma \int v^2 dm$. It is enough that the mass of every particle be found in the expression, multiplied by the square of its velocity.

In the article Virtual Velocities we see the equation—

$$\Sigma mv^2 = \Sigma m \int (\mathrm{X}dx + \mathrm{Y}dy + \mathrm{Z}dz),$$

the integral being taken for each molecule over the whole path which it has described since the beginning of the motion.

Presuming a knowledge of the article cited, we may describe the vis viva thus:—Dividing the whole motion of the system, from the beginning to the time under consideration, into an infinite number of infinitely small changes of place, each of those changes is one of the virtual motions which come under consideration in the principle of virtual velocities. And each motion has, generally speaking, its contrary; and one of these two the system would tend to take, and to refuse the other, if its motion were for an instant restricted, so that it could only choose between those two. The one which it would tend to take is that for which $\Sigma m\,(\mathrm{X}\,dx + \text{\&c.})$ is positive. Now, it appears in the preceding equation that whenever the infinitely small motion which is taking place for the time being is that which (when restricted as above) the system would take, the vis viva is receiving increase; when that which it could not take, decrease. And the vis viva is the balance, so to speak, of all the sums of moments, each with its proper sign, added, also with its proper sign, to the vis viva at the beginning of the motion. [Physical Force, Conservation of.]

The preceding equation is sometimes said to express the principle of the *conservation of vis viva*, which is to be understood thus: the system never acquires nor loses any quantity of vis viva from the action of its parts upon each other, but only from the action of external forces. If after a certain time all external forces cease, from that moment $\Sigma m\,(\mathrm{X}\,dx + \text{\&c.})$ is $= 0$, or $d\,(\Sigma mv^2) = 0$, or Σmv^2 remains constant.

Another remarkable property of the vis viva is, that in all the cases which occur in nature, the amount of vis viva acquired in passing from one position to another depends only on the co-ordinates which settle the initial and final positions. If X, &c., be functions of co-ordinates only, it generally happens that $\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz$ is an integrable function, and depends on co-ordinates only. But the force of this result is not easily seen by the beginner.

At the end of the 17th century a remarkable discussion took place on the question of the mechanical interpretation of the vis viva. Leibnitz first gave this name: he considered force when it produces motion as *vis viva*, or living force; but when it is equilibrated, he called it *vis mortua*, or dead force; and he measured the effect of living force by the mass multiplied into the square of the velocity. To take the simple case which was mostly appealed to:—If two equal weights be thrown up in vacuo, the one with a velocity double that of the other, it is well known that the one will rise, not *twice*, but *four* times as high as the other: accordingly, Leibnitz considered that the force which produces the double velocity is four times as effective as the other force. Various other instances were produced in which the duplication of the velocity is the quadruplication of the effect produced. It was accordingly argued that, for a given mass, the square of the velocity is the proper measure of the force necessary to destroy or to create the velocity. But, on the other hand, it was very well known that, whatever might be adopted as the measure of force, it was certain that pressures were, *cæteris paribus*, proportional to the simple velocities produced by them in a given time. John Bernoulli adopted the opinion of Leibnitz, which was opposed by various other contemporaries; and the controversy (the history of which may be seen in Montucla) continued until the publication of D'Alembert's work on dynamics, in which the question was treated as being purely one of words.

It was objected to the opinion of Leibnitz, that though the double velocity would give four times the ascent, it ought not to be forgotten that it required twice the time: so that in a given time double the velocity would produce only double the ascent, one part of the ascent with another. This argument was never satisfactorily answered; and while we cannot help thinking that it ought to have been decisive of the question, we draw from it a conclusion different from that of D'Alembert; we cannot think the dispute a mere question of words. It must be granted that, for all purposes in which time is not an element, the measure of the effect of a force may be the square of the velocity, as exemplified in the instance cited. But when is it that a mechanical effect can be properly estimated without reference to the time in which it is produced? The definition of the words measure and effect may thus without doubt be accommodated either to the idea of Leibnitz or of his opponents; and those who disputed on the question without requiring exact definitions might degenerate into a mere question of words. But it ought to have been a question as to what was the *proper* meaning of the word effect, in the fundamental phrase "effect of a force," the proper explanation of which must precede all good reasoning in mechanics. If pressure be defined as that which produces a certain effect [Pressure] on our senses, undoubtedly it is a known fact that uncounteracted pressure produces motion; but it is only when allowed to act for a finite time: consequently, the element of time is as essential to the conception of the phenomenon as that of pressure or motion. Height in a rectangle gives area; but it would not therefore be allowable to measure that area by the height; for there must be a base, or there is no rectangle at all. But if pressure be merely considered as the cause of motion, and called force in that sense, it is very difficult to see why the cause, which is only known by the effect, is to be measured by anything but the simple effect. Probably this discussion gave rise to the chapter of the 'Mécanique Céleste,' in which Laplace speculates upon what the laws of motion would have been if force had been as a function of the velocity, instead of as the simple velocity. We have never met with any one who could give us an intelligible account of the meaning of this investigation.

VISCIN. [Birdlime.]

VISCOUNT, the name of a dignity which ranks fourth in the peerage, immediately above that of baron. It is the most recent English title, having, it is said, its origin in the time of Henry VI., who, in 1440, created by letters patent John, Lord Beaumont, Viscount Beaumont. In Scotland the title of Viscount was first granted by James VI.

Camden observes that, although this is a new title of dignity, yet it is an ancient one of office: viscount, *vicecomes*, the deputy of the count or earl, is the Latin name for the sheriff of a county [Sheriff], an office in ancient times held by persons of the highest rank. Whether the title of viscount was suggested by that office it is difficult to say; but Spelman mentions that William the Conqueror made Baldwin hereditary Viscount (*vice-comitem*) of Devon and Baron of Okehampton; and "he made Ursus or Urso Abtot viscount of Worcester, but Roger his son was deprived of the title by Henry I., because he had killed a certain servant of the king; the office, however, was transferred through his sister to the Beaumonts." Spelman seems in these passages to consider this title as one of dignity before Henry VI.'s time, and as having been distinct from that of sheriff: in the first instance he joins it to the title of baron and gives it precedence; in the second, he treats the Beaumonts, who are usually deemed the first viscounts, as only restored to a title which had been in abeyance or forfeited for three centuries. In the British peerage, in 1861, there were 22 viscounts; and there were 41 Irish viscounts, of whom 10 held British peerages also, with 5 Scotch viscounts, of whom 3 held British peerages.

(Spelman, title *Vice-comes, nomen dignitatis;* Camden's *Britannia* (Gough's), i., cxciv.; 2, 299; 4, 24.)

VISHN'U (from *vis'*, "to enter," or "to pervade") occupies the second place in the Trimûrtti, or Triad of the Hindus, and is the personification of the preserving principle. There is no doubt that his worship is of a very ancient date; but at the same time it is evident that it has experienced successive and considerable changes, and that the forms under which Vishn'u is now worshipped in India are far from being authorised by the ancient scriptures of the Hindus. (For his place among Vaidik deities, see VEDA.)

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* On this point, and many others connected with the history of mechanics, the reader will find specific accounts and valuable references in Walton's 'Collection of Problems on Theoretical Mechanics.'

There is no trace of Vishn'u or anything relating to him in the Institutes of Manu, although the allusions which are made to idolaters and the worship of inferior gods (book iii., v. 152, 164) might possibly have some reference to him also. However, we might be led to expect that more notice would have been taken of him by Manu, since the two heroic poems, the Mahâbhârata and the Râmâyan'a, which are generally believed to belong to the same period of Hindu literature as the Dharmma-S'âstra, or Institutes, have for their subjects two of the latest incarnations of this god, who therein assumes the attributes of the one supreme god. He is stated to have appeared before the other celestials, and to have agreed, at their humble request, to become man for the purpose of destroying the demon Râvan'a [SANSKRIT LANGUAGE AND LITERATURE], and to remain incarnate among men for the space of eleven thousand years in order to protect the world after saving it. ('Râmâyan'a,' book i., sect. xiii., s'l. 23.) The Mahâbhârata relates the exploits of Vishn'u as Krishna; and the Hari-Vansa, a sort of supplement to that poem, details his genealogy, and a variety of legends exalting his power and recommending his worship. From the numerous allusions which these poems make to the other Avatâras, descents or incarnations of Vishn'u ('Râmâyan'a,' i., xxiv. 22; xxvii. 2; lxvii. 15, &c.), we may safely conclude that at the time of their composition his history had already been brought into a system, where the miraculous deeds which he performs seem calculated to call forth the special adoration of the Hindus.

The order in which these different Avatâras are supposed to have taken place is by no means fixed, and the discrepancy in the different authorities with regard to Vishn'u's actions on earth is sometimes very great. The 'Vishn'u Purana, a System of Hindu Mythology and Tradition,' translated by the late H. H. Wilson, and published in 1840, contains a full account of them. The last Avatâr is yet to come. These Avatârs, there can be little doubt, represent some physical force or power. Professor Max Müller, in his paper on 'Comparative Mythology,' published in the 'Oxford Essays' in 1856, has shown, from philological deductions, that much of the early mythology of most nations has been formed from "the absence of merely auxiliary words;" and that "there are many mythes in Hesiod, of late origin, where we have only to replace a full verb by an auxiliary in order to change mythical into logical language." But, he observes, the Puranas offer no assistance to the comparative mythologist. "The stories of S'iva, Vishn'u, Mahâdeva, Pârvati, Kali, Krishna, &c., are of late growth, indigenous to India, and full of wild and fanciful conceptions."

Still, as the believers in Vishn'u are numerous in India, it may be interesting to give a slight sketch of the various sects. First, we must state that Vishn'u's heaven is called Vaikun't'a; for a description of which we refer to the first volume of Ward's 'View of the Religion, Literature, &c., of India.'

His names are as numerous as those of S'iva, and may be found enumerated in the Krîshn'a-nâmasahasram, or "the thousand names of Krîshn'a :", they are also partly given in the Amarakosha (i. i. 1.), and of these we shall adduce those which occur most frequently, and are sometimes the cause of a good deal of confusion. They are Kes'ava, Dâmodara, Hrîshîkes'a, Mâdhava and Madhuripu, Janârddan'a, Achyuta, Govinda, Padmanâbhi, Vâsudeva, Trivikrama, Purushottama, &c.

By his wife Lakshmî, the goddess of beauty, he had Kâma or Manmatha, the god of love. The Purân'as, which are the text-books for the Vaishn'avas, are the Vishn'u, Nâradîya, Bhâgavata, Gârud'a, Pâdma, and Varâha, which are called Sâtwika, or pure and true.

Sects of Vaishn'avas.—The first authentic records we have of the different worshippers of Vishn'u date from the 8th or 9th century of our era. At that time the two great divisions of Vaishn'avas and S'aivas were in a flourishing condition, and each embraced six subdivisions; those which belonged to the Vaishn'ava faith are the following:—

1. The *Bhâktas*, who worshipped Vishn'u as Vâsudeva, and wore no characteristic marks; their worship was that of the one supreme lord of the universe.

2. The *Bhâgavatas*, who thus called themselves from a name of Vishn'u, and impressed upon their persons the *Vaishn'ava* insignia, representing the discus, club, conch, &c., of their divinity. But they had an admixture of superstition in their religious creed, and reverenced the *Tulasî* plant and the *Sâlagrâma* stone, of which more will be said hereafter. The authorities of both these sects were the Upanishads and the Bhagavad-Gîtâ.

3. The *Vaishn'avas* differed only from the preceding sect by promising themselves a sort of sensual paradise after death in Vaikun't'a.

4. The *Pancharâtrakas*, who worshipped the female personifications of Vishn'u.

Besides these there were, 5, the *Vaikhânas'as*, and, 6, the *Karmmahînâs*, who abstained from all ritual observances.

These six sects, of which some have disappeared, have given rise to about twenty different schools, which for the greater part exist to this day. Amongst other divisions of less importance, the Vaishn'avas are usually distinguished into four principal Sampradâyos, or sects, of which the most ancient and respectable is the S'rî Sampradâya, founded by the Vaishn'ava reformer Râmânuja Achârya, who lived about the middle of the 12th century. The establishments of the *Râmânujîyâs* are still numerous in the Deccan, and the same country comprehends the site of the *Gaddi*, or the pillow-seat of the primitive teacher; his spiritual throne, to which his disciples are successively elevated; and this circumstance gives a superiority to the Achâryas of the south over those of the north of India. The worship of this sect is addressed to Vishn'u and to Lakshmî, and their respective incarnations, either singly or conjointly; and this causes many subdivisions according as these Vaishn'avas adore either Nârâyan'a or Lakshmî, or Lakshmî Narâyân'a, or Râma or Sitâ, or Sitâ-Râma, &c. Images of metal or stone are usually set up in the houses of the private members of this sect, which are daily worshipped, and the temples and dwellings are all decorated with the Sâlagrâma stone and the Tulasî plant. A peculiarity of this sect is that they always cook for themselves, and observe the most scrupulous privacy in eating their meals.

The chief ceremony of initiation in all Hindu sects is the communication by the teacher to the disciple of the *Mantra*, which generally consists of the name of some deity, or a short address to him. It is communicated in a whisper; that of the Râmânuja sect is, *Om* Râmâya namah, that is, *Om* Salutation to Râma!

The Hindu sects are usually discriminated from each other by various streaks (*Bhaktichchheda*) on their faces, breasts, and arms; for this purpose all the Vaishn'avas employ a white earth called *Gopîchandana*, which should be brought from Dwârakâ, it being said to be the soil of a pool at that place, in which the Gopîs drowned themselves when they heard of Krîshn'a's death. (This word means the "sandal-wood of the Gopîs," and is nothing but a kind of calcareous clay.) The followers of Râmânuja have for their authorities the *S'rî Bhâshya*, the *Gîta-Bhâshya*, the *Vedâsht'a-Sangraha*, and the eight Sâtwika Purân'as; besides numerous other works which are still current in various parts of India. The doctrine contained in these books is called the "Vis'isht'âdwaita," or doctrine of unity with attributes; for although the Râmânujas maintain that Vishn'u and the universe are one, yet, in opposition to the Vedânta school of philosophy, they deny that the deity is void of form or quality, and regard him as endowed with all good qualities, and with a twofold form—the supreme spirit, *Paramâtmâ*, or cause, and the gross one, the effect, the universe: and in these assertions they are followed by most of the Vaishn'ava sects.

The members of this sect are in the north of India called S'rî-Vaishn'avas, and are decidedly hostile to the S'aivas; nor are they on friendly terms with those Vaishn'avas who worship Krîshn'a, although they acknowledge that deity to be an incarnation of Vishn'u.

Towards the end of the thirteenth century of our era, Ramânanda, originally one of the earliest teachers of the tenets professed by the preceding sect, retired from the society, and established a schism of his own at Benares. The principal object of worship of Ramânanda's followers is Vishn'u as Râmachandra: they of course reverence also the other Avatâras, but they maintain the superiority of Râma in the present or Kali yuga; hence they are collectively known as *Râmavats*. They also reverence the Sâlagrâma stone and the Tulasî plant, and their forms of worship correspond with those of the Hindus in general; but some mendicant members of the sect consider all forms of adoration superfluous, beyond the incessant invocation of the name of Krîshn'a, and Râma. They are known as *Vairâgis* or *Viraktas*. There are many subdivisions of this school, which it would be tedious to enumerate.

A sect of great influence, to which the most opulent part of the population of India belongs, is that of the Rudra-Sampradâya, or Vallabhâchâris. They attach themselves to the worship of Krîshn'a and his mistress Râdhâ, one of the Gopis of Vrïndâvana, either singly or conjointly. There is, however, another form which is more popular still, although much interwoven with the other. This is the Bâla Gopâla, or the Infant Gopâla (Cowherd—a name of Krîshn'a), the worship of whom is very widely diffused amongst all ranks of Hindu society, and which originated with the founder of the Rudra Sampradâya, Vallabha Achârya. The worship of Krîshn'a as one with Vishn'u dates evidently from the Mahâ-Bhârata, and his juvenile forms are brought pre-eminently to notice in the account of his infancy in the Vishn'u and other Purân'as; but none of these works discriminate him from Vishn'u, nor do they recommend his infantine or adolescent state to peculiar veneration. Eight times a day ceremonial worship is paid, and the procession of Jugganâtha is (or was) held in his honour. The most popular festival at Benares is the Janamasht'amî, the nativity of Krîshn'a, on the eighth day of Bhadra (August). Another is the Râsa-yâtra, or annual commemoration of the dance of the frolicksome deity with the sixteen Gopîs. This last is a very popular festival, and is celebrated with the greatest solemnity.

The Brahma Sampradâya is a sect instituted in the south of India by Mâdhava Achârya, who was born in the Saka year 1121 (A.D. 1199). The doctrine of the members of this sect is similar to that of the Rudra Sampradâya, with the exception that they deny the Moksha, or final emancipation; they also hold the Yoga to be impracticable: for according to them life is one and eternal, dependent upon the Supreme (Vishn'u), and indissolubly connected with, but not the same with him; they quote the following line from the Mahopanishad: "As the bird and the string, as juices and trees, as rivers and oceans, as fresh water and salt, as the thief and his booty, as man and objects of sense—so are God and life distinct, and both are ever indefinable;" and this one from the Garud'a-Purân'a: "From the difference between omniscience and partial knowledge, omnipotence and inferior power, supremacy and subservience, the union of God and life cannot take place." This division of the Vaishn'avas is however confined to the peninsula, and is altogether unknown in Gangetic Hindostan.

Besides these sects, which are the most conspicuous, the Vaishn'avas comprehend the Khâkis, Maluk Dâsis Senais, Mira-Bais, Nimâvats, Charan'a-Dâsis, &c.

This account of the Vaishn'ava sects has been chiefly derived from Professor Wilson's valuable paper in the fifteenth volume of the 'Asiatic Researches,' to which we refer the reader for fuller information.

Most of these religious sects are divided into clerical and lay members, as it were: the bulk of the votaries, though not always, belong to the latter; while the rest, or clerical class, are sometimes monastic and sometimes secular. Of the cœnobitic members of the different communities most pursue a wandering and mendicant life; indeed all of them at some period have led such a life: but when old and infirm they sit down in some previously existing *math*, or monastery, or establish one of their own.

The Maths, Asthals, or Akâras, the residences of the monastic communities, are scattered over the whole country; they generally comprehend a set of huts or chambers for the Mahanta, or superior, and his permanent pupils; a temple sacred to the deity whom they worship, or the Samâdh, or shrine of the founder of the sect, or some eminent teacher; and a Dharma Sâlâ, one or more sheds or buildings for the accommodation of the mendicants or travellers, who are constantly visiting the Math. Ingress and egress are free to all: and indeed a restraint upon personal liberty seems never to have entered into the conception of any of the religious legislators of the Hindus.

Of the inanimate objects sacred to Vishn'u the Sâlagrâma stone is the principal; it forms a profitable object of traffic, and enjoys the highest veneration of most of the Vaishn'avas. The Sâlagrâmas are mostly ammonites, found in the bed of the Gandhaki river, of the size of an orange. The reasons why this stone is worshipped are very contradictory and by no means satisfactory. We refer to the most plausible ones in the 'As. Res.,' vol. xii.; W. Hamilton, 'Description of Hindostan,' vol. i.; Forbes, 'Oriental Memoirs,' vol. iii.; and Ritter, 'Erdkunde,' vol. iv.

VISIER. [Vizir.]

VISION. [Light; also Eye, in Nat. Hist. Div.]

VISITATION. [Archdeacon; Bishop.]

VISITOR. [College; Uses, Charitable.]

VISUAL DISTANCE. The relative position in which objects are seen is usually expressed by the relative direction of lines drawn to them from the eye; and the angle contained by two such lines is the *angular* or *visual distance* between the objects. [Distance.] *Visual magnitude* may be estimated in a similar way, forming what is called the *visual angle* or *apparent magnitude* of an object.

VITELLIN. A form of albumen found in the yelk of eggs. [Albumen.]

VITREOUS ELECTRICITY. [Electricity, Common.]

VITRIFICATION. [Glass.]

VITRIFIED FORTS is a name that has been given to certain remarkable stone enclosures existing in parts of Scotland, which appear to have been subjected to the action of fire. Attention was first called to the subject by Mr. John Williams, a civil engineer of the last century, who had examined some of them while conducting certain mining operations in the Highlands under the orders of the Board of Annexed (or Forfeited) Estates in 1773, and who, in 1777, published a disquisition about them, under the title of 'An Account of some remarkable antient Ruins lately discovered in the Highlands and Northern Parts of Scotland: in a Series of [13] Letters to G. C. M., Esq.' 8vo. Edinburgh. Williams gave these piles the name of vitrified forts, unhesitatingly assuming that they were artificial structures. Nevertheless the idea, that the so-called forts were of volcanic origin, which had been previously held by Scottish writers, was soon after started anew by Pennant, who had seen one of them, and was taken up by other speculators; in particular it was attempted to be established by the Hon. Daines Barrington, in a paper read before the Society of Antiquaries in 1781, and published in the sixth volume of the 'Archæologia' the following year. But this notion may be said to be now given up on all hands. The subject has also been discussed by Dr. James Anderson and other writers in the 'Archæologia,' the 'Memoirs of the Wernerian Society,' the 'Transactions of the Royal Society of Scotland,' the 'Statistical Account of Scotland,' and of late years at some length by Dr. John Macculloch in the 'Transactions of the Geological Society of London,' and in his 'Highlands and Western Isles of Scotland;' by Dr. Hibbert, as the result of a series of inquiries set on foot by the Society of Scottish Antiquaries, and published in the fourth volume of their 'Transactions,' and by Mr. D. Wilson, in his 'Archæology of Scotland.'

The original description of the general nature of the vitrified forts given by Williams has not been corrected or contradicted in any material point by subsequent observers. And his views were supported at the time, on chemical and other considerations, by Dr. Black, and also by James Watt, who (apparently before the subject had attracted the attention of Williams) had personally and carefully examined the same fort (that on the hill of Craig Phaidrick, or Craig Patrick, near Inverness) which Pennant had hastily inspected. A description of this fort by Watt and a letter from Black are subjoined to Williams's account.

Every vitrified fort Williams had seen was situated on the top of a small hill, overlooking and commanding a surrounding valley or plain, always having at the summit a level area of greater or less extent, and for the most part inaccessible or very steep, at least on one side. Indeed, he asserts that the hills are always difficult of access, except in one place, which has everywhere been strengthened by additional works, of which he gives a description. What is called the fort consists of a wall enclosing the level summit, generally, in part at least, rectilineal and rectangular, but sometimes having one or more of the sides curved to suit the shape of the area. Exterior to this is sometimes a second circumvallation, which in some instances approaches within a few yards of the first, in others is removed from it to a considerable distance; but this outer enclosure is merely constructed of loose blocks of stone; it is the inner wall only which is entirely or partially vitrified. Williams's account is, that the materials have been "run and compacted together by the force of fire; and that so effectually, that most of the stones have been melted down; and any part of the stones not quite run to glass has been entirely enveloped by the vitrified matter; and in some places the vitrification has been so complete, that the ruins appear now like vast masses or fragments of coarse glass or slags." Generally, however, it would appear that the vitrification is not so complete as this description would seem to imply, though it may be sufficiently applicable to the more perfect specimens: in many cases the fire has only given the wall a coating of glass; in some, only one side of the wall is vitrified. The walls appear to be, in almost all the forts that have been examined, partially thrown down; in some, "the vitrified ruins," Williams states, "are nearly all grown over with heath and grass, and often appear at first sight like the ruins of some earth or sod buildings:" from the instances in which the structure seems to be the most entire, it may be conjectured that its original height was commonly about twelve feet.

Above fifty of these vitrified forts in all have been found, dispersed over the shires of Inverness (in which they are most numerous), Ross, Cromarty, Banff, Moray, Argyle, Aberdeen, Perth, Forfar, Kincardine, and Bute. Two or three have also been discovered in the southern counties of Wigton, Kirkcudbright, and Berwick. The most celebrated are that on the hill of Knockfarril, or Knockfarril na Phian, that is, the Place of Fingal on Knockfarril, on the south side of the valley of Strathpeffer, two miles to the west of Dingwall in Ross-shire; that, already mentioned, on the hill of Craig Phaidrick, two miles west of Inverness; that on the hill of Noth, in Aberdeenshire; that on Dun MacSniochain, in Argyleshire; that on the hill of Dunadeer, in Aberdeenshire; that near Creich, in Sutherland; that near the church of Amwoth, in Kirkcudbright; that on the hill of Dunskeig, at the entrance of Loch Tarbert, in Argyleshire; that on the castle hill of Finhaven, four miles to the east of the town of Forfar; that on the hill of Laws, near the village of Drumsturdymuir, a few miles to the north-east of Dundee; that at the entrance of the bay of Carradale, in Cantyre; that in the parish of Kingarth, in the Isle of Bute; that (very slightly vitrified) on Barryhill, in the parish of Meigle, Perthshire; those on Castle Finlay and Dunevan, in Nairnshire; that called Tordun Castle, about three miles from Fort Augustus; that on the west side of Gleneves, in Lochaber, about three miles south from Fort William.

Setting aside the theory of the volcanic or otherwise accidental origin of the vitrified forts, which appears to be untenable, seeing that they are manifestly artificial structures, we have still two suppositions between which to choose in accounting for the appearance they present. The vitrification may have been part of the process of their erection, and designed as a substitute for the ordinary cement; or it may have been the result of accident afterwards. The latter view was suggested by Lord Woodhouselee so early as 1783, and has since been supported by Dr. Hibbert and Sir George Mackenzie; the former, which was that taken by Williams and other early investigators, has been ably defended in recent times by the late Dr. John Macculloch. It is impossible for us here to enter at length into the considerations which have been advanced on both sides: they amount for the most part to but slight and unsatisfactory probabilities. Dr. Hibbert's notion is that the inclosures were intended for the protection of beacon fires; and he has endeavoured to show that the elevations on which they are erected are so chosen as that one of these signals could always be seen from another. His views are adopted by Mr. Wilson in his valuable 'Archæology of Scotland,' before referred to. Dr. Macculloch, on the other hand, maintains that this is not the fact. Besides, he observes that the extent of most of the enclosures is far beyond what could have been required for any beacon fire: the area of that at Amwoth, for instance, is not less than 2700 square yards. How also, it is asked, should it have happened, as is generally the case, that the walls should be vitrified on both surfaces, the exterior as well as the interior, if the effect was produced merely by the flame of a beacon lighted up within the inclosure? That they were intended for defensive military posts, Dr. Macculloch further contends, is manifest from the whole character of the works—both the vitrified walls and the surrounding defences, all of which, he says, "vary in form and size according to the ground they stand on, and are so contrived, just as a military work would be in the hands of a modern engineer, that they may command all the points of access, and prevent the enemy from advancing anywhere under cover." Macculloch further sought to show that the material of which the walls are built has evidently been selected with a view to its capability of being vitrified. But, as Mr. Wilson observes, his statements "only confirm the fact, already familiar to the chemist and geologist, that there are few districts in Scotland where rocks do not occur more or less capable of being vitrified." The materials that have been commonly used are granite or moorstone, limestone, sandstone, and what is called pudding-stone, all of which have the quality of being more or less easily fusible by fire. None of these forts are found south of the Tweed; they appear indeed to be peculiar to Scotland.

VITRIOL. A name formerly given to the sulphates. Thus the terms green, blue, and white vitriol were applied to sulphate of protoxide of iron, sulphate of copper, and sulphate of zinc respectively. Sulphuric acid is now sometimes termed *vitriol*, or *oil of vitriol*.

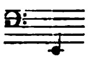
VITRIOL, WHITE. [ZINC.]

VIZIR, or VEZIR, is the name of the ministers of the sultan of the Turkish empire, and is also given as a title of honour to several other high functionaries, civil as well as military. The word is of Arabic origin, and means literally "the bearer of a burden," as *vezr* designates "the action of bearing or carrying a burden." Some write *wazír*, or *vazír*; but this is not correct. From *vizár*, a substantive which expresses the action of supporting a prince in the administration of his empire, is formed *vizáret*, the dignity or function of a vizír, which we generally call *vizirat*. There are two plurals of vizír: the Turkish plural, *vizírler*, which is the common; and the Arabic plural, *vuzerá*, which occurs in imperial decrees, as for instance, in "*vuzerài* 'izámi zeví-l-íhtirám," "the illustrious grand vizírs." The post of a prime minister, who directs state affairs when the sovereign either will not or is prevented from doing it, is a very ancient institution in the East; and the lieutenant of a king was called vizír by the Arabs long before this title was adopted by the Turks-Osmanlis. The first Turkish vizír was the celebrated 'Alá-ed-dín, the son of Osman, founder of the Turkish empire, who was appointed to the post of prime minister by his brother, Sultan Urkhan, in A.H. 726 (A.D. 1326). Until the reign of Mahmoud II. the grand vizír was almost the sole minister; but his power was then much circumscribed. He is now only the head of the ministry, and the other ministers have distinct departments and titles, as in European governments. At first there was only one vizír. But Timur-Tash (Ironstone), a general of Mürad I., having gained a great victory over the Turks-Seljuks of Caramania in A.H. 788 (A.D. 1386), his master gave him the title of vizír, and the then vizír, 'Ali Pasha, was created "vizír 'azim,"—that is, the great or illustrious vizír. From this time the number of vizírs was gradually augmented: Mohammed II. had seven; Mürad III., six; Mürad IV., nine; but from the time of Ahmed III. there were only seven vizírs who were real ministers. The title of vizír is likewise given to the Begler-Beys, or governors, of Rumelia, Anatolia, and Damascus, to the four high judges, the grand equerry, the sirdar, or field-marshal, the chief master of the forests, and to several other high functionaries; and in former times it was given to the silihdar, or armbearer of the sultan, and to the agha of the janissaries, two dignities which are now abolished. Sometimes, also, this title is conferred upon governors of Sanjaks, as was the case with the famous 'Ali Pasha of Janina, after his victories over the French in 1798. The title is now considered as ranking next below that of Mushir, or field-marshal. The insignia of a vizír are a splendid dress of velvet embroidered with gold, pearls, and precious stones, a turban with an ornament of diamonds, and a standard, to the top of which are attached three horsetails, and which is carried before them by an officer: hence the title of pasha of three tails, which is identical with vizír. The dress of the grand vizír is still more magnificent than that of the common vizírs, from whom he is distinguished by several privileges: he receives the solemn visits of all the high functionaries, including the common vizírs; he commands the centre of the army in battle; and, except the sultan, he is the only person who is saluted with the "alkish," a kind of benediction pronounced by those who appear in the presence of the grand vizír. The words of the "alkish" are, "Allah ömerler were efendümüze!" (God give a long life to our master!)

(Hammer, *Des Osmanischen Reiches Staatsverfassung*, &c.; *Geschichte des Osmanischen Reiches;* Kieffer et Bianchi, *Dictionnaire Turk-Français*, sub. voc. 'Vizír' and 'Alkish.')

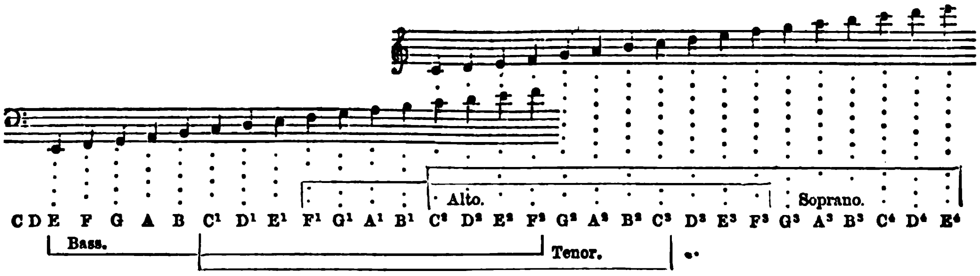
VOICE. The voice (from the Latin *vox*) is an audible sound produced in the larynx. The design of the present article is to treat of the sounds of the human voice in its two great functions of Song and Speech. The nomenclature and notation of music [MUSIC] are here adopted, with such an extension, based upon the same principles, as is necessary for the purpose.

The infinite varieties of sounds heard in the human voice are all embraced under the general terms Pitch, Loudness, Quality, and Duration.

The scale of the human voice, from the lowest note of the bass to the highest note of the soprano, within which limits composers write vocal music, is four octaves in extent, namely, from *mi*, E,  in the bass cliff to *mi*, E^4, in the treble cliff. There have been instances, but they are very rare, of voices capable of descending lower, and others of ascending higher than those limits. This scale of sounds is divided into *voce maschile* (male voice), which extends from *mi* (E) in the bass to *do* (C^3) in the treble cliff; and *voce feminile*, or *voce biancha* (female voice) which extends from *fa* (F^1) to *mi* (E^4) in the treble cliff.

The lower or male voice part of the scale is subdivided into Bass and Tenor, each containing two octaves: the bass extends from *mi* (E) to *fa* (F^2); and the tenor extends from *do* (C^1) to *do* (C^3).

The upper or female voice part of the scale is subdivided into Contralto and Soprano, each containing two octaves: the contralto extends from *fa* (F^1) to *fa* (F^3); and the soprano extends from *do* (C^2) to *mi* (E^4). These are the four scales within which musicians compose vocal music for each class of voice. The following diagram exhibits the scale of the human voice and the relation of its subdivisions:—


Alto.
Soprano.
C D E F G A B C¹ D¹ E¹ F¹ G¹ A¹ B¹ C² D² E² F² G² A² B² C³ D³ E³ F³ G³ A³ B³ C⁴ D⁴ E⁴
Bass.
Tenor.

N.B. The terms *Alto*, *Contralto*, and *Counter-tenor* are the same.

Intermediate between the bass and tenor is another male voice, extending from *la* (A) to *fa* (F^2), and termed the Barytone. And between the Contralto and the Soprano is another female voice, extending from *la* (A^1) to *la* (A^3), and termed the Mezzo-Soprano. The voices of eunuchs and boys are classed with female voices.

By reference to the diagram it will be seen that the scales of the several voices overlap each other in the great compass of the human voice; thus the bass overlaps the tenor eleven notes, so that the tenor descends to within five notes as low as the bass; while the bass ascends to within four notes as high as the tenor. Eleven notes are common to both bass and tenor scales, and any music whose variations of pitch are within the range of those eleven notes can be sung either by a tenor or a bass voice. It appears also by the diagram that a tenor voice reaches to within three notes as high as the contralto, and mid-way up the soprano compass; giving twelve notes common to the tenor and contralto, and eight notes common to the tenor and soprano scales, which explains the wide range of music which tenor voices can sing.

The ordinary compass of a voice is about twelve notes. Many singers' voices however extend to two octaves; some even beyond two, and some have reached three octaves. Catalani's compass is said to have been three and a half octaves.

The compass of soprano and some other voices is divided into registers, of which there are two, namely, the natural and the falsetto. The former is termed in the Italian school *voce di petto*, which means chest voice; and the latter *voce di testa*, which means head voice. To these the Italians add another, which joins the two registers, and which somewhat partakes of the character of both; it is named the *mezzo falso*, or middle falsetto. The extreme upper notes of the falsetto are by some termed the *flautino*, or flute register, but this appears to be an unnecessary subdivision. The following table exhibits at a view the voices and their registers :—

Bass	Chest			
Barytone	Chest			
Tenor	Chest	Mezzo-Falso	Falsetto	
Contralto	Chest	Mezzo-Falso	Falsetto	
Mezzo-Soprano	Chest	Mezzo-Falso	Falsetto	
Soprano	Chest	Mezzo-Falso	Falsetto	Flautino.

In this musical distribution of the registers of the voices there is no falsetto given to the basses. The bass and barytone voices however are both capable of extending their compass by running up into a falsetto, and hence they must each have a mezzo-falso register also. The falsetto is commonly adopted by bass singers to imitate a woman's voice in the opera buffa.

There is also a feigned lower voice by which voices of all kinds are able to descend lower in pitch than in the natural register. The term basso-falsetto has been proposed to designate this voice, but the term lower falsetto is more accurate.

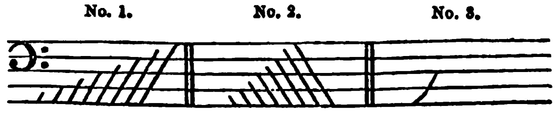
The Quality of the Voice.—Each person's voice has a distinct quality or tone (*timbre* of French authors), by which it is recognised, even when singing in unison with others. The terms which are adopted to describe the qualities of the voice are vague: they are descriptive, such as nasal, guttural; descriptive by comparison with other sounds, as silvery, flute-like, musical; and metaphorically descriptive, as pure, clear, deep, brilliant, flexible, attractive, mellow, &c. Attempts have been made to connect certain qualities of the voice, as fulness with the bass, brilliancy with the soprano, &c., but without success. It is however quite true that those who are accustomed to hear much singing would mostly recognise any voice to be a bass, tenor, &c., although singing in unison with contraltos or sopranos. The essential distinction however between voices, as the bass and tenor, is not the quality, as stated by some physiological writers; for a voice is classed among basses or contraltos, as the case may be, solely in consequence of its compass lying within the limits of the bass or contralto scales.

Each voice has its natural and falsetto qualities, which belong respectively to the natural and falsetto registers. Besides these there is in song an improved quality named pure tone, and in speech a corresponding improved quality named the oratorical tone.

Song-voice.—The song-note is a musical sound of some fixed pitch in the musical scale. When a clear resonant voice produces a song-note, the accompanying harmonic sound may be heard just as it is with the sound of a vibrating string. The song-sounds of the human voice are arranged into the diatonic, chromatic, and enharmonic scales. [MUSIC.]

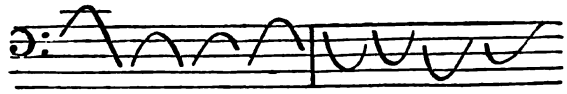
Speech-note.—The speech-note is not a true musical sound, because its pitch varies throughout its duration. These notes are termed slides, accents, and inflexions; and they may be imitated on the violin by sliding a finger up the finger-board while the bow is applied. These notes may have an ascending or descending course in pitch, and sometimes they have both on a syllable. The varying pitch of a speech-note will be illustrated if the reader, with an intense feeling of inquiry utter aloud Hamlet's interrogatory "Pale, or red?" The speech-note on the word "pale" will consist of an upward movement of the voice; while that on "red" will be a downward movement, and in both words the voice will traverse so wide an interval of pitch as to be conspicuous to ordinary ears; while the cultivated perception of the musician will detect the voice moving through a less interval of pitch while he is uttering the word "or" of the same sentence. And he who can record in musical notation the sounds which he hears will perceive the musical interval traversed in these vocal movements, and the place also of these speech-notes on the musical staff.

Speech-notes are of two kinds, namely, simple and compound. The simple consist of a single rising or falling movement of the voice. These movements may be of any extent from a semitone up to an octave. These differences of extent give eight simple rising speech-notes, namely, semitone, tone, third, fourth, fifth, sixth, seventh, octave, and as many simple falling speech-notes, making a total of sixteen distinct simple speech-notes. Mr. Steele accurately represented these notes by diagonal lines on the musical staff. The length of the line indicates the interval or dimension of the note; and its situation on the staff indicates its local pitch, as in the annexed diagram, Nos. 1 and 2, where the eight notes ascending and descending are in accordance with Mr. Steele's notation.



In these notes the sliding movement of the voice is equable, that is, it passes through equal spaces in equal times. The voice however in some notes is retarded in some part of its course, so that it passes through unequal spaces in equal times. Mr. Steele noted this retardation of the voice by slightly curving the diagonal line at the part, as in the above diagram, No. 3. Now the voice may be retarded at the beginning, at the middle, or at the end of a speech-note. And the voice may be accelerated in each of those parts. It will be seen that these modifications of pitch greatly multiply the number of speech-notes. And this number can be again greatly increased by successively giving to each note all the various forms of loudness of voice of which it is capable.

The compound speech-notes consist of both the simple vocal movements combined in a variety of circumflexes. They were first noted on the staff by Mr. Steele, from whose 'Prosodia Rationalis' the following diagram is copied :—



Numerous as are the varieties of circumflexes, they admit of classification, of which the following, partly taken from Dr. Rush, is adopted :—

The number of constituent vocal movements.

1. Simple circumflex consists of two movements.
2. Compound circumflex consists of three movements.
3. Continuous circumflex consists of more than three movements.

The direction of the first vocal movement.

1. Direct circumflex has the first an upward movement.
2. Inverted circumflex has the first a downward movement.

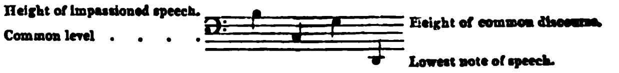
The dimensions of the vocal movements.

1. Equal circumflex, each movement of equal dimension.
2. Unequal circumflex, each movement of unequal dimension.

In forming a circumflex speech-note, the voice may be retarded or accelerated in parts, as well as move equably through its course. The possible varieties of circumflex are almost infinite, and the number in ordinary use is far beyond what would be anticipated. This will account for the immense variety of sounds which are heard in human utterance, and which has been more a subject of declamation than thoughtful inquiry.

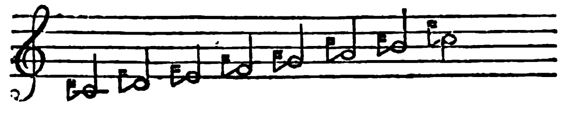
The Compass of the Speech-voice.—Several of the rhetoricians of antiquity speak of the changes of pitch of the voice seldom exceeding a fifth on any one syllable. Observations conducted for twenty years on the leading public speakers of the period have convinced the author of this article of the accuracy of this ancient statement. It is true that higher intervals are used, even up to the octave, but very sparingly, and the fifth itself is of less common occurrence in oratory than the third.

Speech melodies seldom exceed the limits of an octave and a half. Whatever the speaker's key note may be, he seldom rises more than a fifth above it, or descends more than a fifth below it in pitch. A person's key note is generally somewhat below the middle of his compass, which circumstance enables most speakers to ascend an octave if required for the purpose of expression. The following notation of Mr. Steele's speaking compass, taken from the 'Prosodia Rationalis,' is interesting :—

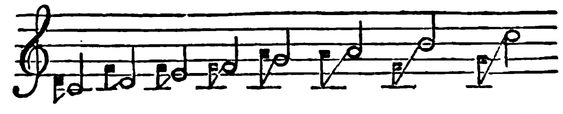


The voice of song (that is, a song-note) has been described as continuing throughout its duration on one level line of pitch. This description was necessary at the outset in order to state the essential distinction between song (musical) sounds and speech sounds.

Close observation however of the song-notes of singers, especially in dramatic music, will show that many of the notes are not of uniform pitch, but that the voice rapidly slides through some interval, commonly of a tone, and the song-note is produced at its summit. Let the slide be equal to a semiquaver, and the song-note a minim, or rather to a minim minus the semiquaver slide, which is stolen from the quantity of the song-note: many singers reach the several degrees of the scale by these slides according to the subjoined notation :—



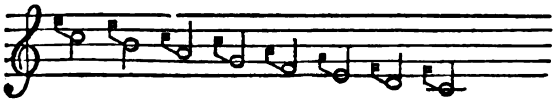
In taking the intervals from a fundamental note, it is not uncommon to hear a rapid slide through the entire interval, producing slide thirds, fourths, &c., and the song-note at the summit of the slide, according to the subjoined notation :—



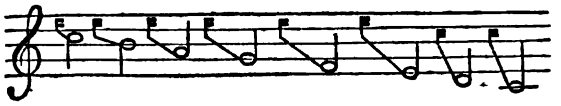
Similar notes often occur in the passionate intonation of the wide intervals of operatic music.

These song-notes closely approximate to those speech-notes in which the movement of the voice is retarded at the upper part of its ascent; and the approximation is the nearer in proportion to the greater retardation.

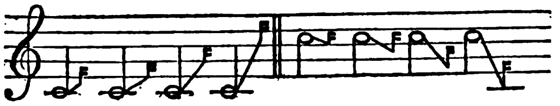
Sometimes the song-note is preceded by a rapidly descending slide, which may be of the interval of a tone, as in the subjoined diagram:—



The slide is however frequently heard of greater intervals, especially in the musical expression of high excitement of feeling, as in the subjoined diagram:—



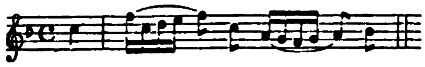
In song a rapid slide is occasionally heard after the song-note. The slide may either rise or fall in pitch, and it may be of a tone or of a higher interval. The subjoined diagram is a notation of such notes, with a tone, 3rd, 5th, and 8ve, respectively, ascending and descending:—



The after-note of song (*Nachschlag* of the Germans) being always on the weak part of the measure, the slur from its principal to it produces a slide as above noted. These however are rarely heard.

A slur in song binds two or more notes into one continuous sound by a rapid slide of the voice, and thus approximates to a speech-note. In the following illustration taken from Callcott's 'Grammar of Music,' p. 83, the effect of the first slur is similar to a circumflex speech-note, of equal intervals and inverted flexure; and the second slur is in effect similar to an unequal inverted circumflex:—

"Our limpid streams." Joshua.



The preceding illustrations are given with a view of indicating, and not of exhausting, the subject.

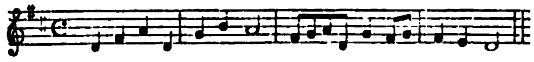
Of Recitative.—The notes of song, of speech, and the mixed notes above described, are all to be heard in recitative. The speech and the mixed notes predominate over the pure notes of song.

Of Chant.—In chant also are to be heard the notes of song, speech, and the mixed. The rapid part of the chant consists of speech-notes, and the concluding syllables of the clausular divisions are sung on song and mixed notes.

Of the kinds of Melody in Song, Speech, Recitative, and Chant.

Song.—A succession of single sounds forms a melody or tune. [MUSIC.] A melody is said to proceed by *degrees* when its successive notes are in proximate degrees of the scale; and a melody proceeds by *skips* when it omits or leaps over one or more degrees of the scale. In general, degrees and skips are intermixed, as in the melody of the Easter Hymn, taken from Callcott's 'Grammar:'—

"Jesus Christ is risen to-day."

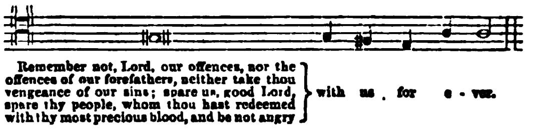


In the incantation scene of the opera of 'Der Freischutz,' Weber has produced an effective melody, consisting of a repetition of the same sound. For the rhythmical arrangement of the sounds in song, see MUSIC, RHYTHM, and PROSODY.

Speech.—In speech, as in song, a succession of single sounds constitutes a melody. A speech-melody formed of speech-notes may proceed in all the varieties above described of song. [ELOCUTION.] In vocal music the rhythmus of the language bends to that of the music. It is musical rhythmus. In speech-melodies however the rhythmus is that of the language.

Recitative.—Recitative melodies also proceed in all the varieties of song. In accompanied recitative, although the musical rhythmus takes the lead, yet the singer has much latitude, and in a great degree controls the musical rhythmus. In unaccompanied recitative the musical rhythmus entirely yields to the singer's ideas of what is appropriate to the required expression.

Chant.—Chant melodies also proceed in all the varieties of song. The ordinary melody however consists of a rapid iteration of the same note through a clause to the concluding four or five syllables, which are set in an appropriate succession. The following notation from the Litany, as arranged by the Rev. P. Penson, of Durham Cathedral, is quoted from the Leeds Church-Service, edited by Mr. Hill, the choir-master:—


Remember not, Lord, our offences, nor the offences of our forefathers, neither take thou vengeance of our sins; spare us, good Lord, spare thy people, whom thou hast redeemed with thy most precious blood, and be not angry
with us . for e - ver.

The first note, *sol*, G, is rapidly reiterated on each syllable to the last five. The rhythmus is left to the taste and feeling of the chanter. In both recitative and chant the words are more distinctly uttered than in song. This arises from the structure of the notes, which are chiefly either speech-notes or those song-notes which approximate to them, in both of which distinct utterance is infinitely easier than in the notes of song.

Of the Voice as a Natural Language of the Emotions.—The voice, whether it be or be not united with verbal language, is expressive of the feelings. The voice is the language of the feelings, by which they manifest themselves to the ear without previous teaching; and when heard, are recognised and felt without teaching. The scream of terror, the shout of joy, the laugh of satisfaction, the laugh of sarcasm, the laugh of ridicule, are made by man and understood by his fellow-man, wherever the one may be born and whatever may be the speech of the other. The voice is a natural, a universal language. Each mental attribute has its voice, which is in relation to that attribute; and whether that attribute form part of the mind of man or brute, it instantly recognises the voice. The piercing cry of pain, the affrighting scream of terror, the voice of joy, are common to all, and recognised by all. The voices of the feelings, so far as pitch, duration, and loudness are concerned, are capable of notation. Dr. Colombat has attempted the notation of cries arising from various pains: and Dr. Burney has noted the song of several birds. The changes of pitch present the most remarkable changes in the voice; and on these mainly depend the voices of the feelings. The mind adopts changes of pitch to express its condition, and the interval of music is but a means of measuring, and thence imitating, that expression. A higher intensity of feeling increases the interval. Composers know this fact, and avail themselves of it in dramatic music. The pages of Handel, Mozart, Beethoven, Weber, and Rossini are full of illustrations of it. The "Messiah," the greatest of all musical compositions, abounds with degrees of intensity of the same feeling.

On the Improvement and Preservation of the Voice.—In the improvement of the song-voice the great objects to accomplish are, 1. To improve its quality in clearness and resonance. 2. To make every note in its compass equally pure. 3. To extend its compass both above and below. 4. To obtain power to produce a prolonged note on each degree of its compass. The accurate intonation of the scales is presupposed, for without that all training is musically useless. To effect these objects, various systems of discipline are proposed, but none would be successful without the governing ear and voice of a master. The work, however, of Signor Crivelli stands in the foremost rank.

For the preservation of the song-voice the two great principles are, 1. To be temperate in all things, as eating, drinking, &c.; and, 2. Daily practice in the scales of music.

In the improvement of the speech-voice, the first great requisite is so to produce voice that it may not be injurious either to the general health or to the throat in particular. 2. To improve its quality in clearness and resonance throughout its compass. 3. To extend its compass both above and below. 4. To produce a prolonged speech note on each degree of its compass. These have seldom been systematically attempted, and not only have many orators been limited in their success by the defects of their voices, but many have been obliged to discontinue their avocations, especially the clergy, either from the injury to the throat or to the general health which public speaking produced. The primary object of elocutionary science, like that of physical, is to produce the greatest possible effect with the least expenditure of power; but, as in song-training, no system can be successful without the governing ear and voice of a master. The work entitled 'Cull on Public Reading' contains an outline of speech-voice training which has been eminently successful.

For the preservation of the speech-voice, as for the song-voice, temperance in all things is required; also daily practice in the several forms of speech-note. By this means public speaking may become a pleasurable and healthful exercise.

The ancient orators were accustomed to exercise their voices daily in preparatory declamations, and to ascend and descend through the compass of their voices by repeating about 500 lines of verse from memory. The ancients adopted various medicaments and diets as beneficial to the voice, and certain nostrums are recommended at the present day; but let the orator depend more on a proper exercise of his organs, as the singer does on his, and he will be rewarded with cheerfulness and health.

VOID. [Vacuum.]

VOLATILE OILS. [Oils.]

VOLCANO. The situations on the globe where subterranean fires have made or found channels to the surface of the land or to the bed of the sea, are termed volcanoes. A volcano is merely the channel of upward communication from the subterranean fires; the mountain in which the volcano acts, and the extensive mounds and masses of ashes, lava, &c. (substances hereafter described), which surround it, are the effect and the measure of the expansive mechanical forces which are relieved by the pouring forth of the streams of melted or flowing and plastic rocks, the showers of ashes, torrents of steam mingled with gases, and of water, which constitute the eruptions. By considering the nature of these solid, liquid, and gaseous substances, their mutual relations and respective functions in volcanic phenomena, and the circumstances of their ejection, some progress may be made towards a chemical theory of the nature and origin of the subterranean fires; but to gain a proper notion of the mechanical forces set in action during volcanic excitement, we must enter upon a larger inquiry:—the connection of earthquakes and volcanic eruptions, the relations of one volcanic district with another, especially as to coincidence or reciprocity in the times of their violent activity or remarkable repose; and the history not only of volcanic phenomena which are now in progress or have formerly happened in particular situations, but the general history of the effects of the disturbance of the internal heat during all geological periods and over all parts of the globe. Those mechanical forces, it must be remembered, are simply the correlates of this heat, and come into action, primarily, in consequence of the antagonistic action of the sun's rays upon the surface of the earth, and its more immediate results in changing the position of the matter constituting that surface.

Has this extensive inquiry been followed out so completely and methodically as to justify a belief that the true theory of volcanoes is reduced, as several other branches of the great theory of nature have been, to a plain process of induction? That many geologists suppose so is evident from the decision with which their general speculations are advanced; but the student who desires to possess clear and systematic inferences without being troubled with contending hypotheses will find it necessary to class the phenomena as if the inquiry were very far from completion. The following views may aid his researches into this large and interesting subject:—

Succession of Volcanic Phenomena.—A complete history of any one volcano, by showing us its origin, its alternations of rest and activity, its progress to decay, and its final extinction, would furnish a sufficient base for a general theory of volcanic action; for the analogies among all burning mountains, as to form, structure, composition, and associated phenomena, are such as to warrant the application of a few general laws and one theory to them all. But we know not completely the succession of phenomena which have happened in any one volcano. We have indeed examples in abundance of new islands and new mountains being raised in our own days and giving forth fire; we have the history of Vesuvius as an intermitting volcano for nearly eighteen hundred, and that of Ætna for above two thousand three hundred, years; and we may contemplate on the banks of the Rhine, in Hungary, and in Auvergne, the aspect of a country from which the subterranean fires appear to have withdrawn their forces before (though in the country last named probably not long before) the origin of history. The birth, continued activity, decay, and extinction of volcanoes are phenomena seen in separate parts of the earth's surface, and acquire unity and consistence only by being rightly combined into a correct general view of volcanic action.

Earthquakes.—Previous to volcanic eruptions generally, whether these happen in old craters or burst up in new situations, earthquakes prevail, sometimes for a considerable period, in the vicinity of the volcano, and extend their terrors to considerable distances from it. Near to the centre of future violence springs have been known to fail and others to burst forth, and unusual noises have been heard. Previous to the year 1538 the Neapolitan shore had been disturbed by earthquakes for two years; and these symptoms of subterranean disturbance were succeeded by the production of the Monte Nuovo (on and over the ancient site of the Lucrine Lake) in the space of forty-eight hours.

Among the effects of great earthquakes are fissures in the crust of the earth, both in volcanic regions and in distant situations. In 1811 and 1812 the movements of the ground in the valley of the Mississippi and in Caracas caused vast depressions and elevations, some of which remained, so as permanently to affect the drainage and change the form of the surface. Some of the numerous fissures produced in Calabria by the earthquake of 1783 assumed a radiating form, and it is conjectured by Lyell that in these situations the ground was permanently raised. In 1669 the flanks of Ætna were fissured, and through the opening the Monte Rossi was raised, by ejection of ashes, &c., to the height of 450 feet. In 1759 the new volcano of Jorullo was formed on the plains west of Mexico by the accumulation of ejected materials (as is now known) into a mountain 1695 feet high.

By these instances, taken from situations far from other volcanoes (Jorullo), at points in the vicinity of active and extinct volcanoes (the Monte Nuovo), and on the slopes of a frequently burning cone (the Monte Rossi), it appears that generally the earliest observable fact in the history of volcanic phenomena is the opening of the ground,—

a. Along a line of fissure. *b.* In a system of intersecting fissures. Such openings, when happening on land, constitute subaërial volcanoes; and when occurring in the bed of the sea they produce submarine volcanoes.

The preceding statements relative to the connection of earthquakes and volcanoes, and the alleged elevation of land by the former, are in agreement with the inferences generally drawn from both classes of phenomena prior to the publication of the recent inductive researches on earthquakes, of which, and of their results, we have given some account in the articles Earthquake and Seismology. Seismic and volcanic energy are evidently the same in origin, manifested in the former in a manner purely mechanical, and in the latter in a thermal (if not chemical) and also mechanical manner. But we must now admit that these phenomena are not related as cause and effect. Earthquakes do not produce or commence volcanoes, or initiate, though they may be simultaneous with, volcanic eruptions; nor do volcanoes cause earthquakes, though there is a common cause, or chain of causes, for both. Mr. R. Mallet has shown that fissures even are never produced by the direct passage of the wave of shock in an earthquake, but are a mere secondary effect, conformed to and determined by the dip or slope of the subjacent beds of rock, and are no more than incipient landslips. The movements of the ground in Caracas and in the valley of the Mississippi, mentioned above, were in all probability of this description. In like manner, having deduced from theory, as well as inferred from observation, that earthquakes cannot produce elevations (although the latter have been known to have taken place about the same time as earthquakes and in the same region), he examined with care more than 150 miles of sea-coast, as well as river-courses, for evidence of any permanent elevation of land having taken place even concurrently with the earthquake of the 16th of December, 1857,—the greatest that has occurred in Italy since that of 1783, referred to above,—but found none.

The production of elevations and true fissures appears in fact to be a third great effect, or class of effects, of the common chain of causes of earthquakes and volcanoes,—to be a distinct consequence from them of "the tendency of the globe to swell into froth at the surface," to use the emphatic and comprehensive expression of Sir J. F. W. Herschel. That a volcano begins by the production of a fissure, through which the ejections constituting an eruption are subsequently to be discharged by the continuance of the force originating the fissure, is most probable; though it may often happen that the elevation of such materials from below falls short of an eruption, and merely fills the fissure (afterwards to be observed as a dyke), or that the materials elevated are of a different description, and are not otherwise related to volcanic phenomena than as being effects of a common primary cause—subterranean heat. We shall again have to notice the light thrown upon the philosophy of volcanoes by the recent investigations of earthquake-phenomena.

Eruptions.—When by some movement of the ground a channel is opened from the interior to the surface of the earth, a paroxysm of volcanic excitement follows, and an eruption happens through the new opening. There may be a slow outpouring of melted rock, pressed upwards against gravity by an internal force; or a violent upburst of clouds of scoriæ and ashes, mixed with larger stones; or a torrent of the same materials mixed with water, and constituting mud; or volumes of steam and gases of different sorts; but permanently gaseous matter appears to be much inferior in quantity to aqueous vapour, and frequently, if not generally, to be the least important product or educt of an eruption. These are exactly the products, singly or in combination, which are delivered by long-established vents, and, as far as we can judge, the same have been yielded by volcanoes which probably became extinct before the historic era of the human race; moreover, the volcanoes of all regions agree generally in this respect. Evidently, therefore, the condition of the interior parts of the earth, which are under the influence of volcanic excitement, is of a general and continuous nature, and must be supposed capable of interpretation by examination of the products and the circumstances of their extrication.

The enormous flashes of lightning which accompany volcanic eruptions, issuing from the ascending column of steam and solid ejections, and which are equally characteristic of eruptions originally submarine, when they rise into the atmosphere, have been celebrated from the time of Pliny; but they had not been accounted for in any satisfactory manner, having only been vaguely referred to an evolution of electricity connected with the intense actions of various kinds taking place in the eruption. After Mr. (now Sir William G.) Armstrong had observed the electricity of effluent steam, Mr. Brayley pointed out the precise analogy of the sparks given by it, to this volcanic lightning. ('Phil. Mag.,' Series 3, vol. xviii. p. 94.) Dr. Faraday subsequently ascertained that the electricity of effluent steam is produced, in reality, by the friction of the globules of water, resulting from its partial condensation, and of particles of foreign matter, both merely driven onward by the steam as a mechanical agent, upon the substance of the tube from which it issues. In the eruption of a volcano we have all these elements in perfection, and on an immense scale, the foreign particles being supplied by the volcanic ashes, and we may therefore conclude, that the enormous evolution of electricity accompanying it arises from their friction, as in the hydro-electric machine. It is probably the greatest example in nature of the production of frictional electricity.

Mass of Volcanic Products.—Now the first thing which arrests the attention in regard to the circumstances which accompany the products of volcanic eruptions, is the enormous mass of materials ejected at particular points. In 48 hours, in 1538, the Monte Nuovo, 440 feet high and 8000 feet in circumference, was thrown up in a place which may be regarded as a new vent of the Neapolitan volcanic region. In 1759 a new vent was opened west of Mexico, a new volcanic mountain (Jorullo) was thrown up to the height of 1695 feet, and an area of three or four miles was covered with its lavas. (See col. 670.) Between July and August, in 1831, Graham's Island had been raised from the sea-bed, 100 fathoms deep, to a height of 107 feet above the sea, with a circumference of 3240 feet; in September its height was 100 to 230 feet, and its circumference 2300. In the winter of 1831-2 the whole vast heap of ashes had been dispersed by the waves, and nothing remained of this short-lived volcano but a dangerous shoal. Subsequently this has been lowered, and a comparatively slight elevation above the average level of the neighbouring sea-bed is now under deep water. The lava currents from many volcanoes are of the same gigantic proportions. In 1737 Vesuvius poured forth 33,587,058 cubic feet; in 1794, 46,098,766 cubic feet; and Ætna, in 1669, gave forth 93,838,950 cubic feet, which would make a considerable hill; for it would cover a space of ground one-quarter of a mile across with a conical mound 180 feet high. The accumulated effects of two years' eruptions of Skáptaa Jokul, in Iceland, appear to have filled valleys and lakes and broad plains with floods of melted rock. The lava is said to have flowed in one direction 50, and in another 40, miles, with breadths of 15 and 7 miles respectively, and with a depth averaging about 100 feet, but in places reaching 600 feet. If these data have any claim to be regarded as fair approximations (they are so regarded by Lyell and other writers), the mass of lava poured out in two years by this *modern* volcano exceeds a hundredfold that of the Plutonic rocks which appear in the chain of the Malvern Hills. It would cover all the coal-fields of the British Islands with a plateau of basaltic rock 20 feet thick, or bury London under a mountain rivalling the cone of Teneriffe. In the eruptions of Tomboro, in Sumbawa, in 1815, ashes and scoriæ were thrown out sufficient to form three mountains equal to Mont Blanc, or to cover the whole of Germany two feet deep. The volume of muddy and watery eruptions from volcanoes can seldom be accurately measured. Humboldt speaks of mud eruptions, called "Moya," as frequent in the volcanic system of the Andes, and they are abundant enough to fill valleys and stop the channels of rivers.

From such data as can be collected there appears no sign of any general decay in the magnitude of the volcanic eruptions taken generally, though in respect to any particular volcano the contrary may be inferred.

Eruptive Forces.—If the quantity of matter ejected by volcanoes be taken as a measure of the *amount* of unbalanced pressure which required and obtained relief, the *force* with which it was ejected may be regarded as a measure of the *intensity* of this pressure. Accurate observations on this point are needed. If, as recorded by Sir W. Hamilton, stones were thrown so high above Vesuvius as to occupy 11 seconds of time in falling to the level of the crater, this gives an upward velocity of 350 feet in a second at the level of the crater, and a height of about 2000 feet; but the mountain being above 3000 feet high, we must estimate the pressure at the level of the sea as competent to sustain a column of matter of the ordinary weight of lava (say twice and a half that of water) nearly a mile in height. This would equal the pressure of between 300 and 400 atmospheres.

Lava which had flowed in 1798, was traced by Humboldt to the summit of the Peak of Teneriffe, and must therefore have been sustained (unless the lava were, as is probable, of a lighter kind) by double the pressure. These pressures appear great, but in no degree improbable if judged by the well-known effects of steam. A temperature of 800° Fahr. would give the steam pressure for a height 2000 feet above the cone of Vesuvius; and so rapidly does this power augment with additional heat, that less than 1000° Fahr. may be sufficient to give steam a force equal to balance the whole column of lava in the Peak of Teneriffe. Now these are temperatures which appear to fall within the observed heats of some of the lava currents, for these have been found to melt silver and to perform heating effects greater than those of red-hot iron. Steam-power, generated by the admission of water to the hot interior parts of the earth, appears entirely adequate to the "eruptive forces" actually witnessed in volcanoes. It is much in favour of this being really the agency employed, that we find in explosive eruptions such considerable bodies of aqueous vapour erupted during most parts of the paroxysm; that some eruptions have yielded little else than steam, and others chiefly hot water. Moreover, on considering attentively the distribution of volcanoes over the globe, we find the active volcanoes most frequently by the side of the sea, or by other considerable bodies of water; and the extinct volcanoes in the vicinity of ancient lakes, or desiccated branches of the ancient ocean. Why they should be in the immediate proximity of the ocean or of lakes, will appear in the sequel. But while such proximity undoubtedly facilitates the operation of water in volcanic phenomena, that operation appears not to depend upon it; volcanoes may receive water on account of their vicinity to it, but that vicinity is not occasioned by the necessary agency of water in their eruptions.

The general type of a volcanic eruption appears to be as follows:—The ground is rocked by frequent earthquakes; special movements and noises happen in and about the volcanic mountain; clouds of steam rise from the crater, followed and mixed with showers of ashes and scoriæ driven up by the exploding and expanding vapour; the tube of the crater becomes filled by melted, or at least flowing matter, which undulates upward and downward with the irregular pressure of the vaporous or gaseous matter; these burst in large bubbles through it, scattering it into granular dust and ashes, till the lava overtops or breaks through the loose conical walls of the crater, and flows abundantly, so as partially or wholly to relieve for a time the unbalanced internal pressure.

Volcanic Products.—The substances thrown out during volcanic eruptions, whether stony, liquid, or gaseous, disclose more or less completely the nature and condition of the interior masses of the globe, at depths greatly exceeding the dimensions of the greatest volcano or mountain known, but still very small in comparison to the earth's radius, and belonging to the mere outer crust of the globe. The lava or melted rock is generally referrible to a very small number of aggregations, in which felspar, augite (or hornblende), and oxide of iron are the most important ingredients, the mass being modified by additional minerals, as leucite, idocrase, olivine, garnet, epidote, stilbite, heulandite, and many others. Combinations of sulphur, and of uranium, copper, lead, arsenic, and manganese, also occur in various proportions; but these metallic bodies do not play an important part in volcanic phenomena. The so-called ashes and scoriæ consist of the same substances as the lava, the most prolific repositories of the rarer minerals being always in cavities of the lava or scoriform aggregations. [The characters of these mineral substances have been described under their respective names in NAT. HIST. DIV.]

In these particulars modern lava will bear comparison with ancient Plutonic rocks, for they are composed of similar mineral aggregates, modified by many of the same rarer crystallisations, which mostly occur in the cavities of their mass. The difference of most importance between Plutonic rocks (granite, &c.) and volcanic rocks (trachyte, &c.) is in the degree of their consolidation; and this difference appears quite intelligible by a comparison of the various appearance and character of lava which has cooled and become solid under different circumstances. Lava cooled in air under slight pressure is often cellular; cooled under the pressure of water (as in the case of the current which passed through Torre del Greco into the sea), it is more compact; when vitreous, and much distended by steam, it becomes vesicular pumice. We may therefore believe that lavas which remain and grow solid under great pressure about the internal base of the volcano are of a more dense nature than those which come to the surface, and may thus closely resemble, or be even identical with, some of the older Plutonic rocks, which thus regarded, and from other evidence, appear to be in fact *unerupted lavas*.

The foregoing account of volcanic rocks applies, principally, to one class only of lavas, the stony or common lavas, the most abundant product of volcanoes; but there is a second, the vitreous or glassy lavas, of which the mineral called obsidian, or volcanic glass, is the type, and of which pearlstone and pitchstone and a few other minerals are examples, but partly in a different condition. While the lavas of the greater number of volcanoes belong to the former class (though mingled we believe in those of every one with some glassy lava), those of certain volcanoes are exclusively vitreous, of which that of the volcano in the Island of Bourbon is an example. In the flowing state the nature of these two classes of lavas is very different. The vitreous lavas are then essentially in a state of dry igneous fusion, comparable to that of artificial glass, or of metals; but the stony lavas, even while fresh erupted and flowing, are not properly in a melted state, being in fact as truly aggregates of distinct mineral substances while in that state as they are when they have ceased to flow, acquired the character of ordinary solids, and become cold. They are, while they retain the flowing property, as Mr. G. Poulett Scrope first observed and maintained (in his work referred to below) more than a third part of a century since, a sort of mud, consisting of the crystalline grains of the minerals found to constitute them, allowed to slip or glide over each other by the intervention of water or of aqueous vapour in a peculiar condition of condensation and adhesion to the surfaces of the solid particles, though at a red- or even at a white-heat. Mr. Scrope's views, though almost contemptuously rejected at the period of their enunciation, have received great support from the subsequent discovery of the possible existence of water in a liquid state at high temperatures (as they might have received it from a contemporary one of its convertibility into vapour of its own volume), and from the now admitted necessity of the agency of water in the production of all the crystalline aggregates constituting the Plutonic rocks, including granite itself, which has been referred to by Mr. Scrope in a confirmatory paper communicated to the Geological Society in 1856. A remarkable proof, among many others, that the stony lavas are not really in a fused condition, is afforded by the fact urged by Mr. Scrope, that the radiation of heat by them is comparatively so slight, evincing that they cannot possess that intensely high temperature which would be requisite to impart to their mineral and chemical elements a truly liquid state, independently of the agency of water.

The views of this consummate volcanic geologist, however, are now probably to be regarded as forming only a first approximation to a true theory of the nature of lava. The researches which have been subsequently pursued in the chemistry of geology, and in the artificial synthetic production of minerals, as well as in the geology of the metamorphic rocks, and respecting the action of the igneous rocks upon the sedimentary strata, tend to modify the original conclusions of Mr. Scrope, but still only in the manner which has characterised the progress of all great discoveries in science. The necessary agency of water, together with intense heat, in the production of the crystalline rocks, has been urged by Scheerer and E. de Beaumont. Its operation through a great range of temperatures, both in producing and in altering rocks, has been demonstrated or illustrated by Bunsen and Delesse, and more recently by a remarkable series of experiments by Professor Daubrée of Strasburg. He has shown "that the molecular state of the water in lavas, 'be it what it may,' has had a great effect in the formation of silicates, even when anhydrous. It causes them to separate, and to crystallise at a temperature much below their point of fusion; it enables them to crystallise in an order of succession different from that of their fusibility; thus, for example, leucite, an infusible silicate of alumina and potash, occurs in lavas in well-formed crystals, often of large size. To this, Ludwig, in his German translation of Daubrée's essay, adds that the crystals of leucite often contain fragments of lava, and even small crystals of the very fusible mineral augite."[*] These results are most apposite to, and beautifully elucidatory of, the true nature of lava as originally observed by Mr. Scrope. His views, perhaps, would have sooner been entertained by other geologists, had he more explicitly distinguished between the vitreous and the stony lavas when flowing. The former when in the purest and most characteristic condition present us with the state of igneous fusion in its most perfect form; solidifying into glass when rapidly, and crystallising when very slowly, cooled. Taking volcanic phenomena as a whole, there doubtless exists every gradation between this and the hydroplastic condition of lava such as that of Vesuvius and Etna, which, however rapidly cooled, does not solidify into glass, but into an aggregate rock or stone, identical with that resulting from its slow cooling in nature. It is important to observe that the glassy lavas are converted by slow cooling not into stony lava, but merely into the crystalline state of the combination of silicates of which they consist. The stony lavas, however, when truly fused, whether naturally or artificially, become the glassy lavas if quickly cooled, or the corresponding vitrite or crystalline substance if allowed to cool slowly. Such also is evidently the origin of the vitreous lavas in volcanoes, their observed transitions from the glassy to the crystalline or stony form depending partly on their mineral constitution and their condition when in the flowing state, and partly on the circumstances and rate of their refrigeration. Of all this we now possess ample evidence, both geological and experimental. For some of the former we may refer to the facts detailed by Mr. Darwin in his 'Geological Observations on the Volcanic Islands,' &c.; and as an example of the latter, to the results of fusing basalt, which is an ancient lava, and when melted and rapidly cooled becomes a glass scarcely distinguishable from obsidian, but when gradually cooled does not return to its original condition of a stony lava, an aggregate rock consisting of several mineral substances, but becomes a kind of pearlstone—the peculiar crystalline condition of the glass. The importance of these latter facts in reference to the acceptance and right understanding of Mr. Scrope's views has already been urged by Mr. Brayley [Watt, Gregory, in Biog. Div.], and been frequently adverted to by him in lectures on igneous geology.

Water undoubtedly is second only in quantity among the products or educts of volcanic action, to the solid earthy matter, oxides, like it, some of non-metallic combustible, some of metallic bases. Its functions in the origination of Plutonic and volcanic action were first suggested, as we shall find, by the discoverer of the chemical nature of that earthy matter, Sir H. Davy. Those which it possesses in volcanic phenomena themselves, partly in the condition of vapour, and partly it is probable in a peculiar intermediate condition not yet understood, were first truly discovered by Mr. Scrope, and established in his 'Considerations on Volcanoes.' The liquid products of volcanoes also contain, though rarely, the sulphuric and muriatic acids; and among the substances of most interest in aiding to complete the theory of chemical actions, are sublimations of common salt, and muriate of ammonia. The origin of these where the volcanoes are situated by the sea-side cannot be doubtful. Boracic acid is another product of this kind occurring in the crater of volcanoes (Daubeny); but this we now know is an abundant element of the earth's crust, widely disseminated, though but rarely in great quantities in a single locality. Compounds of boron, however, do not appear to play an important part in the history of volcanoes.

The gaseous products of volcanoes are important in the investigation of the chemical theory of the igneous action. Besides the clouds of vapour of water (so abundant in eruptions, and so often productive of local rains), chlorine, azote, sulphuretted hydrogen, sulphurous acid, and carbonic acid, are the most common. The evolution of sulphuretted hydrogen (depositing sulphur) continues under various circumstances after other signs of activity have ceased in particular volcanic regions; and even after the craters have fallen in and become full of water, mineral springs and springs rich in carbonic acid flow with little variation for centuries (many such have been flowing from before the commencement of history to the present day), while azotised waters, rising to the surface along the lines of fissures more ancient than any known volcanic systems, concur with them in demonstrating the almost interminably slow process by which subterranean heat rises to the surface of the earth.

Chemical Hypothesis of Volcanic Action.—The nature of these various products, and the order in which they successively make their appearance, have been the bases for speculations as to the chemical processes going on in the interior of volcanic regions. Sir H. Davy's discovery of the metallic bases of the earths and alkalies, and of the extraordinary appetency for oxygen of several of these bases (potassium, sodium, &c.), suggested to that great chemical philosopher a new and ingenious hypothesis of volcanic action. Water admitted to some of the metallic bodies alluded to is instantly decomposed, and its oxygen absorbed, with an immediate and very remarkable evolution of heat and light, while the metals become earths or alkalies. The substances most abundant in volcanic products contain these earths, and these alkalies,—namely, potash, soda, lime, silica, alumina, &c.,—in various combinations, evidently the result of successive crystallisations from a fluid mass. In this hypothesis it is assumed that the interior portions of the earth consist in part of the metallic bases of the earths and alkalies; that water is from time to time admitted to these; that violent combustion and great heat follow; that the oxides generated are melted together, constituting lava, while the hydrogen, and some of the water undecomposed, go off to form new combinations with sulphur, chlorine, carbonic acid, &c., which are liberated from previous states by the heat and the various chemical agencies set in activity. The power which raises the lava, and throws out the clouds of ashes and scoriæ, is the undecomposed and confined steam.

Whoever looks carefully at this hypothesis will find in it much that is admirable, and little that is open to strong objection, if it be regarded merely as a *theory of the eruption of volcanoes*, not as a theory of the changes in the condition of the interior parts of the globe, of which volcanic action is one of the visible exponents.

It is some recommendation of this view that it seems to unite itself with a general and not improbable speculation regarding the origin of the more ancient Plutonic rocks, which certainly must be supposed to have passed through a very similar series of changes to those which lava has undergone. Those rocks have the same bases as lava; it is the natural result of chemical reasoning, that the elements which are now combined in them existed at some earlier time in a separate state; the oxidated and melted granite crust of the earth is formed by the union of these elements, and, according to the hypothesis of Davy,[*] the new rocks which volcanoes yield are produced by a somewhat similar process of oxidation and fusion.

But this hypothesis was nevertheless neglected by its author for reasons which do not appear to have been fully stated by himself. It was taken up by Dr. Daubeny, and has been maintained by him with much perseverance and ingenuity of research as a sufficient 'Chemical Theory of Volcanoes.' We may call it the 'Hypothesis of Subterranean Oxidation,' and develop it, according to Dr. Daubeny, as follows:—

Below the surface, at a depth of a few miles, the interior of the earth is assumed to contain the earthy and alkaline metalloids, iron and other metals, sulphur and sulphuretted salts. Slow combustion happening amongst them, even under the continents, by slight additions of moisture and air, generates particular gases (nitrogen, carbonic acid, sulphuretted hydrogen, &c.); these rise and combine with springs which issue along lines of natural fissures, or are discovered in artificial wells, often giving to them a temperature higher than that of the country where they occur. Under the sea or large bodies of water, and especially along lines of sea-coast (where fissures may be supposed more numerous than elsewhere), water may be admitted to the interior more easily and in greater quantity, and may occasion phenomena of the same order, accompanied by other effects more powerful, rapid, and characteristic, until the process ceases for awhile by the choking of the passages which admitted the water.

The water, decomposed by contact with the metalloids, yields its oxygen to them; the hydrogen is liberated, but not allowed to escape in great quantity alone, for it readily, under the influence of heat, combines with sulphur into sulphuretted hydrogen, or, with the oxygen of atmospheric air (if any be present), reconstitutes water. Nitrogen is thus liberated, and may be conceived to pass off partly free, partly combined with hydrogen, so as to constitute ammonia, which again unites with chlorine (derived from the sea-water), and constitutes sal-ammoniac. While oxygen (derived from atmospheric air) is plentiful in the volcanic channels, the hydrogen will not unite with sulphur, which accordingly combines with oxygen into sulphurous acid. When the oxygen is consumed, sulphuretted hydrogen is formed in abundance, and predominates towards the close of the eruption, and even, by the aid of the residual internal heat operating on sulphur, is evolved for centuries after the volcanic violence is spent.

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[*] Leonard Horner, F.R.S., Anniversary Address to Geological Society of London, 1861. 'Quart. Journ.' vol. xvii. pp. xlviii—xlix.

[*] 'Phil. Trans.' 1828.

The evolution of chlorine is easily traced to a double decomposition of sea-salt; carbonic acid is supposed to rise from calcined limestone rocks; and specular iron-ore (*fer oligiste*) is a product of sublimation. Thus, in the opinion of Dr. Daubeny, all the main phenomena concomitant upon volcanic action seem to admit of explanation if we suppose, first, sea-water, and afterwards atmospheric air, admitted to considerable masses of metals, metalloids, sulphur, &c., the basis of the whole speculation being the abundant decomposition of water at a moderate depth below the surface of the earth. The views of Dr. Daubeny have been controverted by very eminent writers (as Dr. Davy, Prof. Bischof, and others) on particular points; but we are not aware of any attempt upon other assumptions quite so satisfactory as this of Dr. Daubeny, to explain generally the *chemical products* of volcanic eruptions in the order of their occurrence.

Perhaps, therefore, we may concede to this hypothesis the probability that in the interior of the earth the metalloids exist in quantity sufficient to cause an abundant decomposition of water, and thus originate a given series of chemical changes such as are witnessed in volcanic eruptions. But before we accept it as a *general explanation* of volcanic disturbances, other classes of data than those furnished by chemical analysis must be brought into the reasoning.

An important circumstance in the general theory of volcanoes is the connection and reciprocal activity which exists underground between volcanic regions entirely separated on the surface, as between Sicily and Naples; between the Mediterranean volcanic region, taken generally, and the region of extinct (or long suspended) volcanic action in Asia. To this we must add another and larger series of facts regarding the extent and distribution of volcanic action on the surface.

Volcanic Regions and their Connection.—Volcanic regions, if estimated by the area over which the lava and ashes have been dispersed, constitute but a small portion (perhaps less than $\frac{1}{1000}$th part) of the surface of the globe, but in a survey of these regions we must include not only the active vents and extinct craters, but also "large intermediate spaces where there is abundant evidence that the subterranean fire is at work continuously, for the ground is convulsed from time to time by earthquakes; gaseous vapours, especially carbonic acid gas, are disengaged plentifully from the soil; springs often issue at a very high temperature, and their waters are usually impregnated with the same mineral matters as are discharged by volcanoes during eruptions. (Lyell, 'Princ. of Geology,' book ii., ch. ix.)

To describe these districts would be entirely foreign to the purpose of this essay, but we may by a simple classification show how much of the grandest features of physical geography is due to volcanic disturbance.

European Volcanic Districts.—The Icelandic volcanoes, remarkable for abundant lava streams; the Azores, amongst which new islands have been thrown up; Sicily, including Ætna and the vanished Graham's Island, often called Sciacca, which is properly only the name of the opposite point of Sicily; the Lipari Isles, with Stromboli always burning; the Neapolitan tract, including Vesuvius; Ischia and the Ponza Isles; Santorini and some neighbouring islets. The above are all considered as *active* volcanic centres, and have been subject to eruptions in historical times. The *extinct* volcanic systems of Europe are the trachytic domes in the centre of France (Auvergne, [AUVERGNE, in GEOG. DIV.] the Vivarais, &c.), the Eifel country, the Seven Mountains, and other trachytic and basaltic parts along the Rhine; the Westerwald, Vogelsgebirge, Rhöngebirge; together with the Kaiserstuhl, and many other scattered basaltic hills in the middle of Germany; Hungary, Transylvania, both remarkably rich in trachytes and the vitreous lavas called pearlstones; the Gleichenberg in Styria. In Italy, the Euganean hills and other smaller points appear in the north of Italy; while between Rome and Naples large ancient craters occur, and connect Mount Albano with Vesuvius. (Daubeny.)

Asiatic Volcanic Districts.—Mixed active and extinct volcanic mountains occur about the Persian Gulf, the Red Sea, and the Dead Sea, in the vicinity of Smyrna, in the Caucasus (especially in Mount Ararat), and in the Elburz Mountains, including Demavend. These are, or appear, detached points of more or less decayed, though once powerful, action, fed by inland seas. On the southern and eastern shores of Asia the subterranean energies are still unsubdued, and constitute a long chain of lofty islands and promontories from Barren Island, in the Bay of Bengal, through the length of Sumatra and Java, by Bally, Sumbawa (already noticed), Flores, Celebes, Sangir, Mindanao, Fugo, Luçon, Formosa, Loochoo, Japan, the Kurilian Isles, the magnificent mountains of Kamtchatka, examined by Erman, and the line of the Aleutian Isles, to Alaschka, on the western coast of North America.

African Volcanic Districts.—The African islands are nearly all volcanic, though, as in St. Helena, the action has long been extinct; or, as in the Canary Isles, the localities once devastated now enjoy immunity through the great safety-valve of Teneriffe. (Von Buch.) On the continent, traces of volcanic action appear in the chain of the Atlas; while in the northern as well as in the equatorial portions of the "Mountains of the Moon," now known through Dr. Beke to be a meridional range parallel to the coast, and extending from the north-eastern to the south-eastern regions of the continent, are many active volcanoes. An account of an eruption of one of these, Jebel Dubbeh, in May last (1861), by Captain R. L. Playfair, R.N., was recently communicated to the Geological Society.

The late M. Daussy, geographer to the French Board of Longitude, collected observations of earthquake-shocks received by vessels at sea at various periods, but all within a given limited area, which, according to Mr. Mallet, render the existence almost certain of a vast active volcanic suboceanic area in the basin of the Atlantic, nearly midway between Cape Palmas on the west coast of Africa, and Cape St. Roque on the east coast of South America, or in the narrowest part of the ocean between these continents. This vast disturbed and perhaps partially igneous ocean-floor can be no less than nine degrees, or above 620 miles, in length from west to east, and from three to four degrees, or between 200 and 300 miles, in breadth from north to south. We have thus a submarine volcanic tract in activity beneath the Atlantic, as large in area as Great Britain, and where the bottom of the ocean is rendered uneven in the extreme, immense protrusions, that is, elevations of land, whether persistent or temporary, taking place in deep water.

American Volcanic Districts.—"Along the north-west coast of the American continent," Sir John Herschel states, "the chain of newer igneous formations is almost continuous, and in Oregon attains an immense development; nor are active volcanoes of great magnitude wanting, *but only those parts of the volcanic zone which lie upon the coast-line* contain such, namely, Mount Regnier and St. Helen's, at the mouth of the Columbia river." The Rocky Mountains show many marks of ancient volcanic action, and serve incompletely to connect the long Asiatic line just described with another enormous volcanic system running through California and Mexico, interrupted at the isthmus of Darien, but continued through Pasto, Popayan, Quito, Peru, and Chili, to Tierra del Fuego; in the last locality, however, though there are trap-rocks, there are no active volcanoes. This mighty range of mountains is everywhere parallel to the sea, being only crossed by the line of Mexican volcanoes, which includes the new mountain of Jorullo, and passes perhaps from the West Indies to the Revillagigedo Isles. The volcanic vents are unequally distributed along the great Cordillera: one in California, five in Mexico, and above twenty between this and the isthmus of Darien. South of this point the volcanoes are few, but mostly of prodigious grandeur and frequent activity, the fire issuing from one or other of the mountains, which, according to Humboldt and Darwin, are all parts of one grand swollen-up mass—supporting Cotopaxi, Antisana, Tunguragua, and other huge cones. Only one active volcano occurs in Peru, but nineteen are active at frequent intervals in Chili, and one (Villarica) burns almost uninterruptedly. Here also is the highest volcano in the world, Aconcagua, measuring 23,910 feet. Most of the West Indian islands are volcanic, or partly volcanic and partly calcareous, the limestone being mostly due to the growth of corals, perhaps on the craters or round the slopes of volcanic mounds. A similar view appears applicable to the numerous groups of islands in the Pacific Ocean, in some of which, as the Ladrone Isles and Hawaii, are lofty and active volcanoes.

In general the Banda Isles, New Guinea, New Britain, Norfolk Island, and St. Philip, the Society, and the Sandwich Islands, are principally of volcanic origin. The low lagoon islands, described by Mr. Stutchbury ('Journal of the Bristol Institution') as deriving this form from the growth of coral, have been thought to be so many points of volcanic mounds; but it has been suggested by Darwin ('Trans. Geol. Soc.') that they are points of subsided land, on which the zoophyta attached themselves. Western Australia contains basaltic and other volcanic accumulations.

"The east coast of Australia offers no active volcano, but is marked along its whole extent, from north to south, with evidences of former igneous activity, occurring (in striking resemblance with what prevails on the opposite coast in South America) among the crystalline and transition [primary and palæozoic] rocks which constitute the general seaboard. But the subterranean fires would seem here to have shifted their ground, and taken up a new line of action to seaward, at an interval of from 1000 to 1200 geographical miles from the coast, but still conforming to its curvature, prolonging the series through the Solomon Islands, New Hebrides, and Friendly Islands, to New Zealand. (Herschel, 'Phys. Geog.')

On comparing this synopsis of the geographical distribution of volcanoes with a good map of the world, two remarkable features of that distribution will be obvious: these are, in the words of the philosopher last cited, "Their tendency to a linear arrangement when insular," and "their constant association with coast lines."

In reference to these features, and to the phenomena described in the preceding review of volcanic regions and their connection, Sir J. Herschel resumes: "It seems impossible to disconnect this obviously systematic arrangement with the general evidence we have, from other sources, of the tendency to continued elevation of the coast line of the Andes, and, indeed, of the whole continent of South America, on the one hand, and of the depression over a large portion of the bed of the Pacific on the other—alternations which would naturally result from a change in the incidence of pressure on the general substratum of liquefied matter which supports the whole. The bed of an ocean supported on a yielding substratum may be depressed without a corresponding depression of its surface, by the simple laying on of material, whether abraded from the land, or chemically abstracted from the sea itself. That matter *is* in process of abrasion and transportation from the land into the ocean at every instant, and along every coast line, we know as a matter of fact. We know, too, that all existing strata, however enormous their thickness, *have* been formed at the bottom of the sea, and it is, therefore, no hypothesis, but a perfectly legitimate assumption, that the same process is still in progress, no matter how slowly, from this cause, at least in the vicinity of coast lines; and when we look at the vast amount of organised exuviæ which constitute so large a portion of many of the secondary and tertiary beds—the secretions of mollusca, infusoria, and zoophytes—and bearing in mind the large proportion of continental substance which has been so formed, look to the evidence afforded by deep-sea soundings, and by coral formations, that the same process is going forward in open sea, far out of the reach of coast washing and river deposit (the material being *taken up chemically* by the river and coast waters, and *chemically extracted from them*, when diffused by currents, by the processes of organic life), we shall at once perceive that any amount of pressure on the one hand and relief on the other, which the geologist can possibly require to work out his problem, and any law of distribution of that relief and that pressure, is available without calling in the aid of unknown causes."

In apposition with these views of the physical geographer, taken, as it were, from an eminence based on all science (and to which we shall return), we may appropriately place the most recent view of the relations of earthquakes and volcanoes, regarded on a cosmical scale; that taken by Mr. Mallet in his fourth report, the following portions of which embrace the principal points of the subject, as resulting from his own seismological researches and those of M. Perrey.

"Should it ultimately prove a fact, as rendered probable from the beautiful investigations of Darwin, that there are great areas of gradual subsidence now in motion beneath the Pacific, it may still happen (though it is not probable) that seismic, or even volcanic bands may traverse such areas of subsidence, without materially affecting their general downward movement. Although many portions of the earth's surface now show evidences of vertical instability, either slowly or *per saltum*, occasionally rising or sinking, these effects are all comparatively insignificant in extent. The great formative forces, whatever they were, upon which the elevated land of the great continents and the depression of the ocean-beds depended, have ceased sensibly to act. The function of the volcano and the earthquake in the existing cosmos is not creative, but simply preservative; and vast as they appear to the eye and sense, their effects are very small in relation to the totality of the great terrestrial machine. If, however, such large areas of oceanic subsidence as have been supposed really exist, they will most probably be found situated almost centrally within the oceanic sub-basins, and hence surrounded, but not traversed, by seismic bands [or lengthened tracts subject to earthquakes].

"There is one fact, which is shown by the relative positions of the greatest volcanic areas upon our globe (and these the most active) and of the areas of probable subsidence, that is worthy of fixing our attention.

"It will be observed that the bands of probable subsidence are tolerably adjacent to the greatest seats of volcanic activity, and that the latter generally have subsiding areas at more than one side. Thus, in the Pacific, the band of subsidence is along the great volcanic girdle from Celebes to New Zealand, and thence stretches between (and at one point may cut through) the line of sub-oceanic volcanic girdles, from the New Hebrides to the Marquesas.

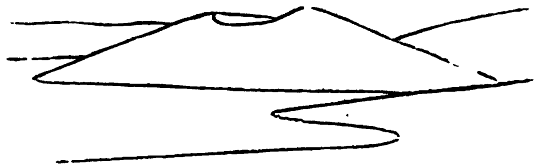
"Again, the great volcanic horseshoe girdle of Sumbawa is between the subsiding area in the China Sea, north of Borneo, and the coral bands north of Australia, which whole continent, or at least its western and northern parts, may probably be subsiding also. Lastly, in the north we have Iceland and its volcanic system, between the sinking coasts of Greenland and those of the Baltic.

"If we admit then, as certain, that these vast tracts are subsiding, we can scarcely withhold our belief that the subsidences are due to, and are the equivalent in bulk of, the solid ejecta and exhalations of these various great volcanic areas respectively. The assumed area and extent of subsidence of those supposed subsiding tracts are, however, I apprehend, greatly overrated.

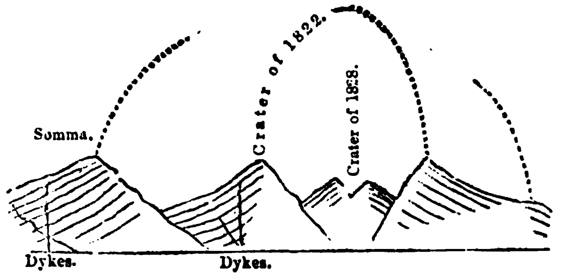
"The seismic intensity in any part of the world, so far as originating impulse is concerned, does not seem to be connected with the superficial character, to the greatest known depth, of the geologic formations, beyond what connection is necessarily inferential from the seismic bands (where they exist), following, on the whole, the lines of mountains and ridges that separate the surface-basins of the earth, whether volcanic or not. While, therefore, the seismic waves diverge from axial lines that are generally of the older rock formations, and often of crystalline igneous rocks, or actively volcanic, they penetrate thence formations of every age and sort, even to plains of the most recent post-pleistocene clay, sands, and gravels; and occasionally, by the secondary efforts of great shocks, these loose materials are shaken or caused to slip, and gather up into new forms (as in the Ullah Bund at the mouths of the Indus, &c.), and so the earthquake has come to be mistakenly viewed as a direct agent of elevation. Its true cosmical function is the very opposite: it is part of the dislocating, degrading, and levelling machinery of the surface of our globe, while the part of the volcano is restoration and renewal. Both are, however, not creative, but conservative (strange as it may sound), and suited to the period of man's appearance and possession of the earth."

The philosophic investigator of the volcanic system of the Canaries (Von Buch) has arranged the groups of volcanoes, which have thus been briefly sketched, into two systems. 1. Central Volcanic Systems, where the vents are grouped round some principal cone, as Ætna, or arranged in an expanded area, as Iceland. 2. Linear Volcanic Systems, as the grand chain of Asiatic Isles and the lofty range of the Andes; and this view is perhaps of the more importance, because it is applicable to the ancient Plutonic rocks, which, from other considerations, we have inferred to be of the nature of unerupted lava. Thus the Sienitic *line* of the Malvern Hills may be contrasted with the scattered *groups* of traps about Charnwood Forest and the country north of the Cheviot Hills.

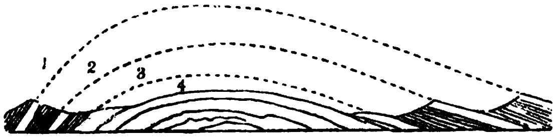
In the one case the crust of the earth has yielded to pressure, and has been broken in many places near a certain point; in the other it has yielded along a certain line of weakness in the rocks. Von Buch imagined that the *central* volcanic systems, like those of the Mont d'Or and the Plomb du Cantal in France, had been originally formed by an uplifting of the ground in a rudely dome-shaped elevation (*Erhebungs-cratere*); while along the linear volcanoes a great fault had occurred. Exactly similar suppositions have been employed for the more ancient examples of unerupted Plutonic rocks; but in each case there is a part certain, namely, the fracture along the line, and a part disputable, namely, the upheaval in a dome. Sir C. Lyell is indisposed to admit in any case the origin of a volcanic vent by upheaval in a dome-like figure; he even dissents from the opinion or narration of Humboldt respecting the elevation of Jorullo by inflation, and from the conclusions of De Beaumont and Dufresnoy regarding the Mont d'Or and the Plomb du Cantal. This is a point which would be of little consequence, but for the interest justly attached to any inference concerning the *origin* of volcanic phenomena. That there have been some rudely dome-shaped elevations in the older strata, in connection with disturbances of the interior of the globe, is evident to any one who has studied the strata in the vicinity of Woolhope, described by Sir R. I. Murchison, of which the subjoined cut gives a cross-section. That the structure of such stratified domes of elevation is entirely different from that of a volcanic cone of eruption is evident by contrasting with the former figure the section across Vesuvius and the profile of the crateriform Monte Nuovo. Some further information on this head appears under the article STRATIFICATION, in NAT. HIST. DIV., and upon the whole it is certain that in respect of a volcanic mountain or region, whose internal structure is sufficiently exposed, there are characteristic marks by which the existence of "craters of elevation" can be affirmatively proved, if any such craters exist. Von Buch, De Beaumont,



Monte Nuovo, 440 feet.



Vesuvius.



Woolhope elevation.

1, Line of the Aymestry limestone; 2, line of the Wenlock limestone; 3, line of the Woolhope limestone; 4, line of the Caradoc sandstone [now termed the Upper Llandovery Rock.]

Professor James D. Forbes, and others agree in ascribing this origin to some of the mountains in central France, and apparently on sufficient evidence. It is, however, not a phenomenon admitting of frequent citation.

Now, the districts thus classed together are not only related by geographical proximity, but have some real subterranean as well as apparent superficial connection. Humboldt and Darwin speak confidently of the great volcanic regions of the Andes as one grand system of subterranean activity; though the manifestations of this at the surface offer local peculiarities, both as to time and circumstances. Mr. Darwin has been led, by the investigation of the volcanoes and earthquakes of the Cordilleras of the Andes, to regard them all as depending primarily on the disturbance of a vast internal sea of melted rock, spread below a large part of South America.

Other conclusions, equally on a large scale, which have been drawn by M. de Beaumont from other classes of phenomena, have a direct bearing on this subject. M. de Beaumont has inferred that the principal mountain-ranges throughout the world have their several geological dates determinable by comparing the positions of the disturbed and the undisturbed strata in and around them: that to each great period of fractures in the earth's crust belongs a certain prevalent direction in which those fractures happened; and though this view may be subject to particular objections and restrictions, there is this great truth in it, that the several systematic fractures which it professes to refer to one certain geological date have each an assignable date. This date being assigned, we find that the earth's crust has in ancient geological times been broken by lines of fracture or bent into flexures, 10, 50, 100, or several hundred miles long, and this often (there are many examples in the British Isles) with no unusual exhibition of really volcanic rock on the line, and even with little appearance of unerupted granite or sienite. These great fractures traverse nearly all regions, with no special reference to active or extinct volcanoes, and it is clear that they are due to a general cause, which has been in operation through all past geological periods, and which produced effects exactly comparable in kind, if greater in degree, to those now performed by modern earthquakes. But if we consider the account of the effects of the great Lisbon earthquake in 1755, which extended over Europe, changing momentarily the level of the land, raising waves 60 feet high at Cadiz, and 18 feet at Madeira, and causing sensible disturbance in the West Indies and Loch Fyne; or the narratives of the Chilian earthquakes in 1822 and 1835, the former of which raised the sea-shore for 100 miles, and the latter rent and shattered the entire provinces of Cauquenes and Concepcion in every direction—it will remain very doubtful in our minds whether the internal power to which earthquakes owe their force has really decreased, or the violence of the earthquake been moderated and relieved by the intermitting action of volcanoes. Mr. Darwin speaks confidently of earthquakes and volcanic eruptions in South America as parts of the same phenomenon, now one and then the other, or both together, but at different points, relieving the pressure on the "internal sea of molten rock;" and this view, which is the largest, appears at the same time the simplest and best founded of all the postulates for a general theory of volcanoes.

This able writer has indeed by a simple inference brought us at once to the basis of this theory. He has inferred that the primary shock of an earthquake is caused by a violent rending of the strata, which on the coast of Chili and Peru seems generally to occur at the bottom of the neighbouring sea.

Here then we take our basis of a general theory of volcanic actions. The earth's crust is subject to fractures, and has always been subject to fractures on a great scale: below the surface of the earth is now, and was in ancient geological periods, an internal sea of molten rock; this sea is agitated and thrown bodily from its place by the rending of the strata: *a wave of translation* (not an ordinary undulation) is generated in the liquid mass [WAVES AND TIDES], which passes rapidly onwards and moves the land on its crest, in a given direction: this is the earthquake. A portion of the melted rock is forced by the general pressure into cavities of the rocks, or spread out in irregular sheets on the bed of the sea; these are the dykes and interposed beds of Plutonic rock: to some part of the internal hot fluid, water finds access, and the steam which is generated and confined supports local columns of melted rock, in particular fissures of the earth's crust, till the lava finds vent and flows to the surface, or is driven up in dust and scoriæ by the violent extrication of the vapour: this is the local volcanic action. As to the composition of that internal sea of melted rock, we may admit it to contain unoxidised metalloids, if by this means we can better explain the peculiar chemical nature of the products which come to the surface; and thus we find at last only one condition remaining to be satisfied, namely, the condition of a continual and progressive destruction of the equilibrium of the internal masses of the earth, which causes the violent rending of the strata antecedent to earthquakes and volcanoes. On this point we need not enlarge. The general progress of geological and physical science has rendered it very probable that the disturbance of the equilibrium of the earth's internal masses, which has at so many geological epochs been exalted to an intensity equal to sink and raise hundreds of miles square, and to fold into complicated contortions the seemingly solid crust of the globe, is due simply to a slow change and gradual diminution of the earth's internal heat. Great fractures, Plutonic rocks, and volcanic accumulations, are of all geological ages; but as our existing land is, in respect of a very large part of its surface, of very recent date, and volcanic cones of loose materials cannot withstand the wasting action of the sea, it is no wonder that the antiquity of volcanoes, if judged only by the relation of volcanic products visible on the land to the stratified crust of the earth, appears much inferior to that of the Plutonic rocks, which were formed among the strata of every age, under circumstances which admitted of their being preserved. But if we more closely study this matter, and compare marine volcanic sediments, such as have been spread by the waves round the base of Sciacca, or Sabrina, with the "trappean" sandstones described by Sir R. I. Murchison interposed amongst the Silurian strata, we shall perceive that local volcanic excitement consequent on general changes in the internal condition of the earth is a phenomenon of all geological periods.

The subject of the production of volcanic cones, whether by eruption or by elevation, or partly by both, has been adverted to in the preceding considerations, and the remarkable example of Jorullo, repeatedly mentioned in the descriptive part of this article, cited from Humboldt as one of elevation. Since their original publication, much research, in which have been observed numerous facts explicatory of the subject, and much reasoning and discussion relating to it, have been instituted and made public, especially by Mr. Scrope, in continuation, or rather resumption of his arguments in support of the reality of the production of volcanic cones exclusively by eruption, by Sir C. Lyell, and by M. Abich, all on the same side.

The most recent view of the subject, in relation to these researches and discussions, taken by Professor John Phillips, F.R.S. ('Anniv. Address to Geol. Soc.' 1859), which it is just to him to quote in this place, is as follows: "In general, it appears probable that cones of elevation are at least of rare occurrence, while cones of eruption are numerous; but as vertical movement of the ground is an essential condition for volcanic excitement at the outset, we must be prepared to admit the possibility of its occurrence as a part of volcanic history: and the only questions which remain for calm and serious study in reference to a given volcano are—How much? and at what epoch? Questions not to be answered hastily." On this point, however, we submit that, however theoretically probable it may be, that vertical movement of the ground is essential to the beginning of volcanic excitement, no proof that it is so has yet been adduced, beyond that required to produce fissures, and ceasing with their production; while induction from the late observations of earthquake-phenomena already noticed, is opposed to it, and some of the results obtained by Mr. W. Hopkins, in his researches in physical geology, appear to indicate that the theory is itself defective, if not erroneous.

Mr. Scrope's recapitulation on this question ('Quart. Journ. of Geol. Soc.' vol. xv. p. 545), states its present aspect in these terms: "My argument then is, that the 'elevation-crater' or 'upheaval' theory, as applied to volcanic action by MM. de Humboldt, De Buch, de Beaumont, and Dufresnoy, and to some extent by Dr. Daubeny and Professor James Forbes, as well as in several popular geological compilations, is an assumption irreconcilable with the appearances it professes to account for, and wholly hypothetical—such a process never having been witnessed; while there is nothing in the form, structure, or composition of any of the cones or craters to which it is applied by its advocates inconsistent with the supposition that they owe their origin to the simple, ordinary, normal, and perfectly intelligible phenomena of volcanic eruptions, as witnessed repeatedly by competent observers as well in the present day as through all past historical times."

Subsequently to the promulgation of these arguments, evidence of the most precise nature, proving that the volcano of Jorullo is truly a cone of eruption, as contended long ago, even on the evidence of Humboldt himself, by Mr. Scrope and Sir C. Lyell, and that it was formed in no degree by upheaval—of which process it had been brought forward by Humboldt as almost a crucial instance—has been given by M. H. de Saussure, a geologist of Geneva, the third in descent, we presume, of a name dear to science. He communicated this evidence to the 'Société Vaudoise des Sciences Naturelles,' in 1859, exactly a century after the surface of the fertile valley of Jorullo had been transformed into a barren sheet of lava, by a catastrophe, having "for one of its results a perfectly characterised volcanic mountain, which suddenly sprung up on the surface of the globe, with unexampled rapidity and grandeur of proportions." Described about half a century after its formation by the great traveller under the influence of an imposing hypothesis, it became one of the subjects, for another half-century, of a controversy among the most eminent investigators of the globe's physical structure. This controversy, we think, as respects Jorullo, must now cease. M. de Saussure states that the sheets of lava surrounding the mountain, called Malpais,—which Humboldt regarded to be the result of a softening of the pre-existing surface soil by gases, and its inflation by them from beneath like a bladder,—are nothing else than vast outflows of incandescent matter, which have lined the whole valley, filling its cavities and forming promontories, just as a mass of molten lead would spread when poured on an uneven surface. The edges of the Malpais are not a section or broken edge of an elevated tract, but only the lateral or terminal borders of currents of lava. The cone which forms the mountain of

Jorullo itself is the simple result of the heaping up of cinders and scoriæ ejected by gaseous explosions from the principal orifice of eruption, after the outbursts of lava had ceased. The eruption took place originally from an axial fissure running north and south, but there is no trace of the elevation of the beds along this axis. The volcanic pressure from beneath had only forced an exit through this fault for the escape of the liquid and aëriform matters erupted. In short, the phenomena of Jorullo show that the most powerful volcanic outbursts can take place without the slightest derangement of the superficial beds. ('Quart. Journ. of Geol. Soc.' vol. xvii.; 'Translations,' &c., p. 13, 14.)

The subject of subterranean heat and its consequences is so vast, and its ramifications in science are so unlimited, that the preceding view of reasonable explanations of Plutonic and volcanic action is far from having exhausted the catalogue. Not merely geologists, mineralogists, and chemists, but astronomers and mathematicians have attempted the solution of the problems involved; the former directing their attention chiefly to special structures, products, or phenomena, the latter to such probable causes as point to hypotheses of wide generality, embracing the entire system of the relations between the earth as a planet to the heat of its interior regions, and to that which it receives from the solar radiation.

While Dr. Daubeny was engaged in perfecting what has been called the chemical theory of volcanoes, originated by Davy, other inquirers gave their attention to that subject under different aspects. Sir C. Lyell, as a uniformitarian in geological speculation, and the advocate, not only of the sufficiency of existing causes, but of their persistence without the trace of a beginning, or the prospect of an end, naturally sought for elements of chemical causation, by which a perpetual circulation of cause and effect returning through effect to cause might be supposed to be maintained; and the late Professor Daniell, of King's College, London, suggested to him hydrogen, with its continual separation from water by means of oxidable bodies and its re-union with oxygen effected by high temperature, as such an element.

Two mathematicians concurred, though independently, in enunciating a theory of Plutonic and volcanic action, dependent on that of the secular variation of the isothermal surfaces within the globe. The foundation of this was the observed augmentation of temperature as we descend from the surface of the earth towards its interior; of which subject we adopt from Mr. W. Hopkins the following condensed statement. A considerable number of observations have been made to ascertain the temperature of the earth at considerable depths beneath its surface, and the law according to which that temperature increases in descending. This law, in a considerable number of localities, may be considered as approximately determined to be—that the increase of temperature above that of the mean temperature at the surface in any proposed locality, is proportional to the depth beneath the surface. The results of observation also lead to the conclusion that the rate of increase of temperature in descending beneath the earth's surface is nearly uniform in each locality, and nearly the same in different localities, being equal to about 1° Fahr. for 60 feet of depth. At all depths, therefore, there will be, mathematically speaking, spheroidal concentric surfaces of the same temperature throughout, or *isothermal surfaces.*

The upward migration of heat from the interior towards the surface of the globe, in consequence of the deposition of fresh matter upon its surface, had been indicated as a cause of geological phenomena by Mr. Poulett Scrope; but the theory of the secular variation of the isothermal surfaces of the interior of the globe considered as so caused was proposed by Mr. Babbage, in a paper read before the Geological Society, in 1834, and by Sir J. F. W. Herschel, in letters communicated to that Society three years afterwards, and eventually printed by Mr. Babbage, together with his own paper, in the appendix to his work entitled 'The Ninth Bridgewater Treatise,' published also in 1837. His application of the theory to volcanic phenomena, properly so called, had been announced, however, in terms of extreme generality, and the main object of his paper was to explain by its means the pyrometric expansion of rocks as the cause of elevation. From these circumstances, apparently, it happened that his views remained comparatively unregarded until the subsequent promulgation by Sir John Herschel of views identical with them in their leading features, but more explicitly developed in their application to those phenomena.

Almost every article in this Cyclopædia which relates to any subject of geological science describes facts, whether structural or dynamical, which involve the truth, that solid materials derived from the land are perpetually being distributed over and accumulated upon the bed of the sea; this having been the process also of the formation of the sedimentary strata of which, mainly, the present land consists. We have seen that it is also true that the temperature of the globe below the surface, and to the greatest depth with which we are acquainted, increases as we descend, the heat communicated to the surface at last escaping from it by radiation into space. By the continued deposition, therefore, of the new sedimentary strata, which are necessarily bad conductors of heat, on the bed of the ocean, the interior heat, instead of being permitted to escape, will be accumulated, and the original surface will acquire the temperature before possessed by some isothermal surface below, at a depth equal to the thickness of the matter deposited upon it, the amount of the accumulation, or the increase of the temperature, augmenting with the increase of this thickness; and consequently, by the necessary extension of this process, the temperature of every isothermal surface vertically below the mass of accumulating matter, to an indefinite depth, will rise in the same proportion. If the temperature at which water boils at the surface, for example, originally existed at the depth of two miles, the deposition of strata of that thickness would cause the temperature of the original sea-bed to rise to that amount; and if the isothermal surface at a certain other depth, of six or seven miles, perhaps, had the temperature of ignition, the deposition of a thickness of sediment equal to that depth would cause the original sea-bed to become red-hot, and, by the continuance of deposition, it would eventually "*become actually melted,*" however refractory its materials, "*and that without any bodily transfer of matter in a liquid state from below.*" This process, to use a familiar illustration given by Sir J. Herschel, "is precisely that by which a man's skin grows warmer in a winter day by putting on an additional great coat: the flow of heat outwards is obstructed, and the surface of congelation carried to a distance from his person, by the accumulation thereby caused beneath by the new covering." In the case of the human body, however, we cannot carry the illustration further: a succession of great coats would not now raise the temperature of the skin, because the heat of the body is limited; whereas the succession of external coverings of the earth will indefinitely exalt the temperature of the original surface of deposition, and successively that of all the isothermal surfaces below, because the heat of the interior, by the theory, is conceived to be, and, so far as we know, is actually, unlimited.

The removal of matter from above to below the sea, in the production of sedimentary strata, produces a subversion of the equilibrium of pressure, and, as we have seen, and which is the most important effect, a subversion of the equilibrium of temperature. But the process, as described, by which this is effected, *must be excessively slow,* and it will depend, "1st, on the depth of matter deposited [as already explained]; 2ndly, on the quantity of water retained by it under the great squeeze it has got; 3rdly, on the tenacity of the incumbent mass, —whether the influx of caloric from below, WHICH MUST TAKE PLACE, acting on that water, shall either heave up the whole mass as a continent, or shall crack it, and [the results of the action of the heat upon the sedimentary matter and the water] escape as a submarine volcano [or a linear series of such volcanoes, afterwards to become subaërial and insular], or shall be suppressed until the mere weight of the continually accumulating mass breaks its lateral supports at or near the coast-lines, and opens there a chain of volcanoes." For a further account of these and other consequences of the rise of the isothermal surfaces, the reader must consult the original papers of the authors of the induction, or of what, for the sake of convenience, we have termed the "thermotic theory of Plutonic and volcanic action." But we may now refer to Sir J. Herschel's account of the facts of the local distribution and systematic arrangement of volcanoes, cited in a previous column (666), as evincing their entire agreement with his theoretical views here given.

Such being the position of the subject, an effort was now made to deduce from the thermotic theory, in the most general, but also in the most explicit, manner, the chemical theory of Plutonic and volcanic action, and to show that the latter, as originated by Davy, adopted by Gay-Lussac, and explicitly advocated by Daubeny (though Davy's speculation had been rejected by one of the authors of the thermotic theory), was in reality a simple and necessary consequence of the theory of the secular variation of the isothermal surfaces, explained by Babbage and Herschel, and applied by them to account for the same phenomena. This was done by Mr. Brayley, in a Friday evening discourse at the Royal Institution (where, thirty years before, Sir H. Davy had announced his theory), deliverd May 11th, 1838, and published in the 'Philosophical Magazine,' series 3, vol. xii., pp. 533–536.

Viewing the subject in the most general approximate manner, agreeably to the amount of our actual knowledge at the time, and unavoidably disregarding a multitude of modifying considerations which must enter into the discussion of the problem, in order to obtain an exact solution of it, Mr. Brayley first pointed out, on the one hand, how great a thickness of deposited matter would be required for the original surface to attain even a moderate temperature above that due to its geographical position; but, on the other hand, at how insignificant a thickness (or depth), compared to the earth's radius, adequate temperatures for Plutonic action would occur,—all these inferences being founded on the observed law of the increase in temperature in descending of one degree of temperature (1° Fahr.) for every fifty (more accurately sixty) feet of depth. The depths at which the temperatures of boiling water and of ignition respectively would be found, are stated above. At the depth of 26 miles, less than $\frac{1}{150}$th part of the earth's radius, cast-iron would melt, or the temperature of 2786° be attained; at 50 miles depth, a temperature of 5000°; and at 100 miles, only $\frac{1}{40}$th of the earth's radius, one of nearly 11,000°; either of which, from all analogy, would be more than adequate to the effects required; for it cannot be doubted that at such temperatures even the most infusible and fixed bodies known to form the earth's crust would be not only liquified but volatilised.

Davy, after repeatedly advocating his own theory, had finally relinquished it, for reasons which it is remarkable that he should not have seen, were altogether in its support, when the theory was duly followed out—in favour of that of an ignited nucleus of the earth, but admitting at the same time that it was adequate to the explanation of all the phenomena it sought to account for.

After drawing attention to these points, Mr. Brayley proceeded to argue that if the theory of volcanoes dependent on that of the secular variation of the isothermal surfaces were true, then the chemical theory must also be true, as being necessarily involved in the wider generalisation of the former. The grounds of the argument were the following, which, as nearly a quarter of a century has elapsed, we now state in the words of Mr. Brayley's original enunciation of his deduction.

"The new deposits formed at the bottom of the sea by detrital matter must inevitably contain much carbonaceous and other combustible materials derived from organised beings, and these would become distributed sometimes in a finely-divided state, intimately mingled with earthy bodies,—that is, with the oxides of the earthy, alkaline, and common metals. At the exalted temperatures implied in the theory, many of these oxides, including those of the earthy and alkaline bases, would become reduced to the metallic state; the ignited water with which the whole would of necessity be saturated, would be decomposed; its oxygen re-oxidising the bases, and its hydrogen being evolved in an uncombined state. Now one of the most abundant elements in all the detrital matter would necessarily be oxide of iron, which would thus be presented, in a state of minute division, to incandescent, but enormously compressed free hydrogen, by which, agreeably to known results of experiment, it would be reduced to the metallic form, water being re-composed. A new affinity would now come into action: finely divided metallic iron being in intimate contact with the earthy and alkaline oxides, they would be reduced, as in the ordinary method of obtaining potassium and the process by which Davy and Berzelius first succeeded in deoxidising the combustible bases of silica and alumina, and would eventually react upon the water still present. By this constant circulation of affinities, exerted simultaneously in different portions of the heated mass, according to their respective temperatures and to the local distribution within it of the various substances evolved (dependent on their respective properties, as modified by the enormous pressures to which they would be subject), chemical equilibrium would alternately be established and subverted; and all the phenomena and effects of plutonic and volcanic action would ensue."

Mr. Brayley also briefly alluded to Mr. Scrope's "views of the origin and constitution of lava, &c.,"—then and recently considered so anomalous,—"as other probable truths involved in the new [that is, the thermotic] theory," from which indeed they were considered in this discourse to be as necessarily deducible, as, in the present article, they have been advocated as confirmable by known facts.

Unacquainted with Mr. Brayley's views, Professor John Phillips, at about the same time (1838), in his 'Treatise on Geology,' in the 'Cabinet Cyclopædia,' remarked,—"There is not, we believe, any attempt on record to deduce all the *chemical* phenomena of volcanoes from the hypothesis of general heat below the surface of the earth; we must therefore, at present, suppose this is difficult, except upon the admission of that powerful absorption of oxygen from water, which the chemical hypothesis provides." Proceeding to inquire whether the results of the latter "involve the rejection of the hypothesis of a pervading high temperature below the surface of our planet," and replying in the negative, he continues: "It appears to us very clear, that the union of the two speculations here brought into comparison is not only practicable, but reasonable, and even necessary." We have seen, however, that an attempt had been made to deduce all the chemical phenomena of volcanoes from the hypothesis of subterranean heat, by the intervention of the thermotic theory, certain chemical consequences being assigned to the latter. Several years after, Prof. Phillips penned the view of the subject taken in the preceding section of the present article; and his most recent ideas respecting it are stated in the following terms in his first Presidential Address to the Geological Society, 1859.

"That the earth is still fluid within, under the regions of volcanic action, and ever ready to pour out its melted constituents under the pressure of elastic vapour, is evident by all the phenomena of volcanic excitement. Is this fluidity due to the residual heat of the globe, still effective in these regions, or maintained if not excited here by the chemical process of oxidation, by the decomposition of water, and the reunion of one of its elements with the uncombined bases of the earths, alkalies, and metals? The answer, if taken from volcanic phenomena alone, appears ambiguous. The chemical products of volcanoes, indeed, require the admission of water to the roots of the fiery action, and the decomposition of it there; but this seems not decisive of the question, whether the bases of the alkalies and earths and metals exist uncombined with oxygen in these situations, chemists of eminence taking different views of the matter."

"If we take earthquakes for our guide, these tremors appear to follow laws which apply to elastic solids, not undulating fluids, and yet they presuppose a shock or displacement [see col. 669], such as a fluid support for a solid crust might well account for."

All the preceding inductions and speculations, however, will be affected by the conclusions at which we may arrive on a subject of a cosmical nature, and relating to the structure of the planet. This is the probable thickness of the solid crust of the globe, assuming it to consist of a fluid nucleus of high temperature inclosed in a solid shell. The phenomena of the increase of temperature with the depth, and their consequences with regard to the heat to which the bodies composing the crust must be subject at comparatively small depths, as briefly noticed above, have led some geologists to conclude that the crust, or external solid shell, is not of greater thickness than sixty or seventy miles, and others have considered it even less: Mr. Darwin, for example, from his researches on the South American volcanoes, infers a probable thickness of twenty miles only. Mr. W. Hopkins, and Archdeacon Pratt, of Cambridge, Professors Hennessy and Haughton, of Dublin, all mathematicians and physicists, and all having a well-earned right to independent judgment in matters of physical geology, have severally investigated this problem, and the latter two inquirers differ greatly from the former, if not in some degree from each other, in the thickness they respectively assign to the crust. But we are disposed to agree with Archdeacon Pratt, that the result Mr. Hopkins has obtained agrees best with all our knowledge. The numerical result of his refined investigation (1839-1841) is, that the least admissible thickness of the crust must be about one-fifth of the earth's radius; a result which after many years' devotion to physical geology he has recently (1859) confirmed, remarking that, "without assigning any great importance to an exact numerical result," he retained full confidence in the investigation, "as showing that the thickness of the crust could not be so small as 200 or 300 miles, and consequently that no geological theory can be admitted which rests on the hypothesis of the crust being nearly as thin as it has been frequently assumed to be."

This conclusion will necessarily affect all our views relative to the causation of plutonic and volcanic phenomena, on whatever foundation they may rest. The source of volcanoes must be in cavities contained in the solid crust at depths probably not greater than those at which the solidity of the crust had been supposed to terminate, by those geologists who reasoned only from the known increase of heat from the surface downwards. Mr. Hopkins, himself, proposes to explain their phenomena "on the supposition that a portion of matter more fusible than the general mass of the globe, exists in a state of fusion in subterranean reservoirs, forming so many subterranean lakes of determinate extent; in some cases originally distinct; in others, communicating with adjoining lakes by more or less obstructed channels."

The view, however, of plutonic and volcanic action at which we have now arrived, combining the thermotic with the chemical theory, and including also the consideration of the thickness of the earth's crust, will itself require modification, in consequence of Mr. Grove's remarkable observation of the decomposition of water by heat alone, independently of chemical action.* [WATER.]

From this it would appear to follow irresistibly, first, that in the very interior of the globe the elements composing water must exist in a state of separation from each other, as it were rigidly separated by heat; but still, from the immense pressure to which they must necessarily be subject, in a very dense state, so that, upon reduction of temperature—lowering of the heat—they would immediately enter into combination.

Secondly, that even in the superficial lakes of molten or flowing matter, to which, after Mr. Hopkins, as we have seen, we must attribute volcanoes,—universally distributed below the mere surface of the earth,—as shown by Mr. Darwin,—the result of the deposition on the bed of the ocean of new deposits, causing the rise of the isothermal surfaces, as demonstrated by Babbage and Herschel—in the more heated parts of those lakes water will exist, not as steam or as incandescent or ignited water, but as mixed but uncombined oxygen and hydrogen gases. At the same time the mere effect of heat will be modified by pressure, and the chemical action of the bodies present, so that we have here another great result perfectly in harmony with the thermotic theory on the one hand and the chemical theory on the other. But we are not to expect any evidence of the existence of free oxygen and hydrogen below to arrive at the surface, for as the upper parts of the molten flood will be of inferior temperature, in them, or in their ignited solid roof, the gases will reunite into water, and eventually ascend to the surface, as steam, or mingled with the mineral elements of lava, in some state intermediate between those of liquid and vaporous water, to be disengaged as steam in the volcano, and from the surface of currents of lava.

Thus, all the great powers and forces which govern the material elements of the globe mutually act and react upon each other. Pressure and condensation caused by gravity, combination resulting from chemical affinity or attraction, heat, producing alternately rarefaction or condensation, combination or separation, accordingly as it is related to the other forces; the whole being so held in equilibrium between themselves and the antagonistic action of the sun upon the surface of the earth, that the magnitude, figure, order, and beauty of our planet are perpetually maintained.*

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* It has been doubted whether the decomposition of water in Mr. Grove's experiment is really due to the action of heat; but there is no room for doubt that it is due at least to agencies excited by the temperature obtained, or inseparable from it, so that the argument in the text will remain valid. The decomposition is effected *at* the temperature, whether immediately by its means or not, and will not take place at an inferior heat.

(The reader may consult Daubeny *On Volcanoes*; Poulett Scrope's *Considerations on Volcanoes*, and *Geology and Volcanoes of Central France*; Lyell, *Principles* and *Manual of Geology*, and *On Ætna*, in *Phil. Trans.*, 1858; Darwin, *Trans. Geol. Soc.*, *Geol. of Volcanic Islands*, *Geol. of South America*; De la Beche, *Geological Manual*; Caldcleugh, in *Philosophical Transactions*; Humboldt's *Cosmos*, *Travels*, and *Treatise on Rocks*; Von Buch, *On the Canary Islands*; Abich, H., *Ueber die Natur, &c. der Vulkanischen Bildungen in Italien*, and *Vues Illustratives*; S. von Waltershausen, *Atlas de l'Etna*, and *Ueber die Vulkanische Gesteine, &c.*; De Beaumont and Dufresnoy, *On Auvergne*; Beudant, *Hungary*; D'Aubuisson's *Geology*; Bischof, *On Mineral Waters*; Rogers, 'On the Apallachian Chain,' in *Reports of Brit. Assoc.*, 1842; Prof. John Phillips, *Treatise on Geology*; Mitchell, 'On Earthquakes,' *Phil. Trans.*, 1760; Ansted's *Geological Gossip*.)

VOLTAIC ELECTRICITY. [Galvanism.]

VOLTAIC PILE. [Galvanic Battery.]

VOLTAMETER. [Electro-Chemistry.]

VOLUME. This word, as meaning a part of a book, is derived from the old form of a book, a roll (of parchment). But our language takes from the French a sense of which the Latin knows nothing; and *volume* means bulk, size, or solid content. Thus the volume of a sphere is two-thirds of that of its circumscribed cylinder: the volume of a cone is one-third of that of a cylinder of the same base and altitude, and so on.

Under the various words, Prism, Cylinder, Cone, Sphere, &c., will be found the modes of ascertaining their volumes. The mode of finding the volume which is contained under a given surface is a process of the integral calculus, which it would be useless to attempt describing within any limits we could afford.

VOLUMETRIC ANALYSIS. *Volumetrical Analysis.* In chemistry, analysis comprehends that series of operations by which a compound body is resolved into its constituents. Analysis may be *qualitative*, and have for its object the mere ascertaining of the number and nature of the constituents, or it may be *quantitative*, which as well includes the determination of the amount of each ingredient. Quantitative analysis is based upon the great chemical law of definite combining proportions, and may be proceeded with either in a gravimetrical or in a volumetrical manner; that is, a body may be isolated and weighed alone in a balance, and its quantity ascertained; or it may be separated by, and weighed in combination with, another body, whose combining proportion is well known: such is the gravimetric method. The balance, the instrument used for measuring the gravitating force of the compound, may, however, be in part or wholly discarded, and the amount of a constituent of a compound be ascertained by noting the volume of a liquid which is required to be added to the compound before a given effect is produced: such is volumetric analysis. Gravimetry is more generally applicable, but requires an exceedingly delicate balance, with perfectly accurate weights, great skill in manipulation, and the expenditure of a considerable amount of time. Volumetric analysis is only applicable to a limited extent; and the liquids referred to, or standard solutions as they are called, sometimes require considerable care in their preparation; but no elaborate apparatus is necessary. The operation is simple, and easy of execution, and may usually be performed in one-tenth or one-twentieth part of the time necessary for a gravimetrical experiment.

Volumetrical analysis seems to have first sprung from Richter's observations on neutral saline solutions, a research which much aided the discovery of the laws of chemical combination. Quantitive estimation by the balance, or restricted gravimetrical analysis, existed prior to that time, and was constantly appealed to in determining the truth of these laws, because the balance was already well known, and its indications could be relied on. Until chemistry began to be applied in the arts and manufactures, there was little or no demand for expeditious analytical processes; even the volumetrical processes of alkalimetry, acidimetry, and chlorimetry, introduced by Descroizilles, and improved by Gay-Lussac, Dalton, and Faraday, for a long time stood alone; and not until within the last ten or fifteen years did the operation of analysis by measure attract any particular attention, or seem likely to aid, much less to any extent supersede, the old method of gravimetry. Since that time, however, the tendency has been in the opposite direction; and now many of the elements, as well as the more commonly occurring proximate principles, can be estimated by volumetric methods. Gases have been almost exclusively analysed volumetrically, but, requiring special and peculiar treatment, their examination is described under Gasometric Analysis, which is generally looked upon as a distinct and separate branch of chemistry.

An enumeration of all the processes of volumetric analysis would require more space than can be devoted to such a subject in this Cyclopædia: nor would such a list be of value for any length of time. The masterly researches of Bunsen and others have already systematised and extended the applications of many of these processes; in a few years, therefore, it is hoped that an approach to classification may be attained, and that the present inconvenience of having to make, and the difficulty of keeping, so many standard solutions, to a great extent will be got rid of. Moreover, several volumetric methods have already been treated of in this Cyclopædia [Alkalimetry; Acidimetry; Assaying; Chlorimetry; Copper; Soap-Test; Tannin; Urea], so that the subject need only be generally treated of here.

The manner in which the processes involved in volumetric analysis are carried out, will be readily seen on referring to any of the articles above mentioned, or in considering a generally applicable process by Bunsen, presently to be described. The only apparatus necessary are some pipettes and a few accurately graduated measuring-glasses of small and large capacity. One of the latter should be capable of delivering fluid both in a free stream and slowly in small drops. A special measuring-tube, or burette, has been contrived for this purpose by Mohr, and is now generally used for the purpose. *Fig.* 1 is a drawing of the instrument.

Fig. 1.

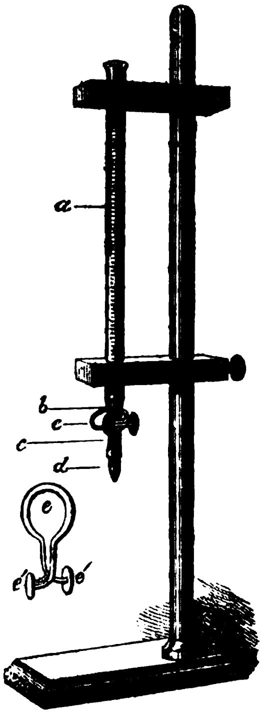


Fig. 2.

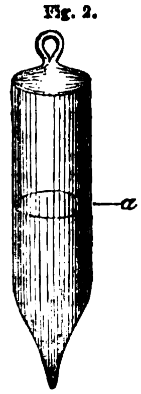
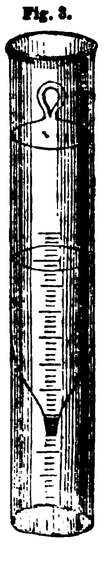


Fig. 3.



It consists of a glass tube, *a*, from three- to five-eighths of an inch wide, contracted at the lower extremity, *b*, and graduated. To the contracted portion is fitted a small piece of vulcanised caoutchouc tube, *c*, into the other extremity of which a small spout, *d*, made of narrow glass tube, is inserted. A wire clamp, *e*, effectually prevents any fluid from passing out of the burette, unless the knobs, *é*, *é*, are pressed by the finger and thumb of the operator, when the liquid either flows or drops as may be wished. The accurate reading off of the height of the solution in the burette is a matter of great importance; Erdman recommends, for this purpose, the use of a float, *fig.* 2. It is a hollow glass bulb, and is used as indicated in *fig.* 3, which represents the upper part of the burette. It must move freely within the burette, and its specific gravity be so adjusted, by enclosing in it a small quantity of mercury, that the upper edge of the liquid in the burette may cut it uniformly on all sides at a line, *a*, marked round the central portion of it. In order also that the line on the float may be parallel with the graduation on the burette, and that no undue friction may exist between the two glass surfaces, the axis of the float must coincide with that of the tube. In cases where the test-liquid contains anything that may act upon the caoutchouc, the end (*b*, *fig.* 1) of the tube may be more finely drawn out and fluid expelled by gradually compressing an india-rubber ball attached to the upper extremity of the burette. Burettes may be specially graduated for a particular class of operations, as seen under Alkalimetry, and Acidimetry; the degrees may indicate measures of ten grains each, as described under Soap-Test; or, as now usually adopted in chemical laboratories, the division may be into cubic centimetres.

By classifying the reactions by which reducing or oxidising volumetric determinations are effected, Bunsen has succeeded in preparing three test-solutions, by which any of the following substances can be quantitatively estimated: mixtures and compounds of iodine, chlorine, bromine, chlorites, hypochlorites, sulphide of hydrogen, sulphites, chromates, chlorates, arsenites; the peroxides of iron, manganese, lead, nickel, &c., protoxide of iron, &c. The fact on which the method is based is as follows:—that when iodine is brought into contact with an aqueous solution of sulphurous acid, containing not more than 0·04 or 0·05 per cent. by weight of anhydrous acid, hydriodic and sulphuric acids are respectively formed:—

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* This view of the effect of Mr. Grove's observation on the chemical part of plutonic and volcanic theory, formed part of a lecture delivered by Mr. Brayley at the Russell Institution, in 1847, shortly after that observation had been communicated to the Royal Society.

$$\underbrace{I}_{\text{Iodine.}} + \underbrace{HO}_{\text{Water.}} + \underbrace{SO_2}_{\substack{\text{Sulphurous}\\ \text{acid.}}} = \underbrace{HI}_{\substack{\text{Hydriodic}\\ \text{acid.}}} + \underbrace{SO_3}_{\substack{\text{Sulphuric}\\ \text{acid.}}}$$

The standard solution of iodine is made by dissolving five grammes of perfectly pure iodine in a concentrated solution of pure iodide of potassium, and making up the liquid to exactly one litre with pure distilled water. This solution (=1000 cub. cent.) will obviously contain 0·005 gram. of iodine in every cubic centimetre. The sulphurous acid liquid is made by adding 35 or 40 cub. cent. of a saturated solution of sulphurous acid to 5000 cub. cent. of water, introducing a little starch paste into some of the solution, and then pouring in the standard solution of iodine until after brisk agitation a distinct blue coloration remains. The value of this sulphurous solution having been calculated according to the above equation, it must be diluted till it contains 0·03 gram. of sulphurous acid in 100 cub. cent. The third test-liquid necessary is one containing about one gramme of pure iodide of potassium in 10 cub. cent. of water. In using these standard solutions for estimating an unknown quantity of free iodine in any substance, a weighed quantity of the latter is taken, the iodide of potassium solution added to dissolve the iodine, (if not already in solution) and the sulphurous acid solution then added until the brown colour of the iodine has disappeared. To effect this, an excess of the sulphurous acid is necessary, but that excess is determined by mixing a small quantity of starch paste with the liquid and then adding the standard solution of iodine until the blue colour appears and remains permanent. The quantity of iodine equivalent to the total amount of sulphurous acid used, less the quantity of iodine afterwards added to neutralise excess of sulphurous acid, will be the amount of iodine present in the portion of substance that was submitted to examination. The great value of this volumetric method of Bunsen depends upon the circumstances that so many bodies may be made directly or indirectly to liberate iodine from iodide of potassium, and that the reactions which occur in the processes are constant, accurately defined, and well known. Any body also which is decomposed by iodine in a known manner can be thus estimated. For example, an unknown quantity of sulphuretted hydrogen in any fluid is at once determined on adding to a given amount of the fluid, first a little starch paste and then the standard iodine solution until a permanent blue (iodide of starch) is produced: as the equivalent of iodine is to that of sulphuretted hydrogen, so is the amount of iodine used to the amount of sulphuretted hydrogen sought for. Hypochlorites are valued according to this method, by mixing a solution of a known weight of the salt with the test solution of iodide of potassium; adding hydrochloric acid till an acid reaction is obtained, and then determining the amount of liberated iodine in the manner already described. Besides a large number of substances which directly liberate chlorine,—and indirectly therefore, iodine,—those substances which are readily and perfectly oxidised by chlorine also come within the range of this method: such bodies may be heated with a known weight of bichromate of potash and hydrochloric acid; every two equivalents of the chromic acid yield under these circumstances three equivalents of chlorine, excess of which must of course be used, and that excess determined, as above indicated, by the amount of iodine it will liberate. For other examples of the adaptation of Bunsen's method, see the English translation of Fresenius's 'Quantitative Analysis,' third edition.

Gay-Lussac's volumetric method of estimating silver by a standard solution of chloride of sodium, has already been described under Assaying. The converse is of course equally easy, namely, the determination of the amount of chlorine in any chloride by a standard solution of nitrate of silver. Mohr has shown that this method admits of very general application: thus ammonia may be estimated by adding excess of hydrochloric acid, evaporating to dryness, and determining the amount of chlorine in the residue; the resulting chloride of ammonium being a definite salt, it is only necessary to know the amount of chlorine in the residue and then a simple calculation will give the quantity of ammonia experimented on. Nitrogen may be determined in a similar manner after conversion into ammonia by soda lime. Carbonic acid may be absorbed in a mixture of chloride of barium and ammonia, the carbonate of baryta collected on a filter, washed, dissolved in hydrochloric acid, the solution evaporated to dryness, and the chlorine estimated as before; the weight of the latter being, of course, transformed by calculation into an equivalent quantity of carbonic acid. Carbonates or nitrates are converted into chlorides, the chlorine estimated, and the equivalent of nitrate or carbonate calculated. Salts of organic acids may be altered to carbonates by ignition, and the carbonates treated as already described. Chlorates, iodates, and bromates are reduced to chlorides, iodides, and bromides, and also acted upon in the way indicated.

Permanganate of potash is a re-agent of considerable value in the volumetric analysis of substances which readily absorb definite quantities of oxygen. Possessed of an intense purple colour, its solution freely gives up its oxygen and becomes almost colourless. It is best standarised by noting the quantity necessary to be added to a known amount of a definite protosalt of iron, such as the ammonio-protosulphate, before a permanent purple tint is produced: this of course only occurs when the protoxide of iron is wholly converted into peroxide. After the strength of the permanganate of potash solution has been thus fixed, it can be used for estimating an unknown amount of protoxide of iron in a weighed quantity of a mixture of the two salts and for other similar operations.

In all the above described processes of volumetric analysis, as well as in those only referred to, a balance and weights or saturated solutions of definite strength are necessary at some stage of the operations. Quantitative determinations can, however, be made without the use of weights, with volumetric solutions of unknown strength, and the strength of which need not be ascertained or regulated. For example, let it be required to know the amount of carbonate of soda in a specimen of crude soda-ash. Place on one pan of a balance a piece of chemically pure carbonate of soda and counterpoise it by the crude ash; dissolve in separate quantities of water, tinge the solutions by litmus, then add dilute acid from a graduated measure until both are saturated; suppose, now, that twenty-two volumes of acid were required for the pure soda and sixteen for the impure, then as $22 : 16 :: 100 : x$, a calculation that shows the crude ash to contain 72·7 per cent. of pure carbonate of soda. Many other determinations may obviously be made on the same principle. The substance to be determined need not even be available in the pure state; one of its compounds must, however, be attainable in that condition, and both that compound and the impure body must be capable of being similarly acted upon by the test-liquid employed. For instance, in the example above worked out, pure carbonate of lime may be substituted for carbonate of soda, but the number of volumes of test-liquid used must be added to or subtracted from according as the equivalent of the substituting body is higher or lower than that of the body substituted.

VOLUNTARY SETTLEMENT. [Settlement.]

VOLUTE, a rolling or spiral curve, a name particularly given to the spirals which appear in architectural columns as ornaments of the capitals. The Ionic volute (figured in Column, col. 49) is that which is of most interest. There has been, we believe, some discussion as to what the form of this curve really was. Whether the architect of a Greek temple employed anything but his eye to give an agreeable form, we do not know; but a mathematician would say beforehand that it would be hardly possible to draw such a number of concentric spirals not interfering with each other as are seen in the diagram above cited, unless each of them was tolerably near to a logarithmic spiral, in which the tangent always makes the same angle with the radius. We examined with particular attention a cast made at Athens by Professor Donaldson, and found the following result:—Taking the diagram in Column (col. 52), we found that each spiral, as far as c, or thereabouts, was remarkably true to the logarithmic spiral: but that from c the law of the curve changed, and the acute angle made by the tangent with the radius vector began to increase, until it became a right angle at a.

VOMICINE. [Nux Vomica, Alkaloids of; *Brucine*.]

VORTEX. The theory of Descartes on the formation and mechanical laws of the universe was first published in 1637, in his 'Principia Philosophiæ.' One part of this theory, namely, the hypothesis of vortices, is almost the only one which generally passes by the name of Des Cartes. But it should be remembered that this is only a part, and a small part, of the system which rendered the Newtonian view of astronomy for a long time unacceptable to the continental philosophers. The metaphysics, the mechanics, and the astronomy, of the once celebrated Cartesian system, combined as they were by one writer, and that writer a most skilful and elegant proposer of his own views, are to be looked at together as that which Newton's philosophy had to meet. Perhaps we should not be wrong in saying that the impossibility of a vacuum, maintained by Des Cartes as self-evident, was a greater obstacle in the way of the theory of gravitation, with which it seemed incompatible, than the theory of vortices, which Des Cartes proposed as an hypothesis, and which did not necessarily contradict Newton's deductions. We shall here present a brief sketch of the system, so far as is necessary, from the third book of the 'Principia Philosophiæ:' this sketch is, as far as it goes, only a table of contents of the work itself.

The human imagination must not either limit the power of God or unduly exalt its own: and it must not suppose that all things were made for man's use only. In enumerating phenomena Descartes prefers rather to deduce them from causes than to make them serve in finding causes. He then describes the relative distances of the planets, and asserts the immensity of the distances of the fixed stars. After the usual statements relative to the light of the sun, planets, and fixed stars, he rejects the Ptolemaic hypothesis, and observes that those of Copernicus and Tycho Brahé differ very little as hypotheses, and explain phenomena in the same manner. He says also that Tycho, though he denies the motion of the earth, yet in reality gives it more motion than the former (with Descartes, relative motion was a most absolute idea); whence, differing from both, he will, with more truth than Tycho, and more care than Copernicus, take away the motion of the earth. To this end he proposes an hypothesis, which will be very fit to explain phenomena; but only as an hypothesis, not as an absolute truth. The fixed stars are exceedingly distant; the sun consists of a fluid and mobile matter, which would carry the circumjacent parts of the heavens with it, but which does not change its place in the heavens: the solar matter does not need aliment. Each one of the fixed stars has an immense space about it, in which there is no other fixed star. The heavens are filled with fluid matter, as astronomers commonly suppose, because they do not see how the phenomena of the planets can be otherwise explained. Each* of the heavens carries with it all bodies therein contained. The earth and every planet is at rest in its heaven, though it may be carried with that heaven: the earth therefore, or any one planet, may be said not to move, but all the others must be said to move. The whole heaven of the sun is moved round it in the manner of a whirlpool, "in modum cujusdam vorticis," the more distant parts moving more slowly than the nearer; and the planets are carried round with this heaven. And as in the larger whirlpool are sometimes seen smaller ones, which are carried round in the larger; so each planet is the centre of a smaller vortex, in which its satellites are carried round their primary. The sun and planets are carried round their axes by the motion of their vortices (the inclinations of the planetary orbits to the ecliptic have an obvious explanation: the inequalities in longitude are mentioned without explanation). It can hardly be that an hypothesis which thus explains phenomena can be false: to say this would seem to be an imputation upon the Deity, namely, the supposition that He made us so imperfect, that a right use of reason might lead us to deceive ourselves (Descartes is not the only one who has used this sort of argument). Nevertheless, he is willing that it should be put forward only as an hypothesis. And though both religion and reason teach that God made the world complete, that not only the seeds of plants were formed, but plants themselves, &c., yet the nature of things will be better explained if it can be shown how, as from seed, the solar system was produced (Descartes here fears the imputation which was afterwards cast upon the author of the *nebular hypothesis* [SOLAR SYSTEM]). All matter originally consisted of particles, forming numbers of fluid heavens, revolving about their several axes. These particles were originally equal in size and motion; they also became spherical, when the corners had been worn down by rubbing against each other. And since no portion of space can be vacuous [VACUUM], the interstices of these spheres must be filled by matter, of form perpetually changing, derived from the parts worn off the angles: this last kind of matter moves more quickly than the other. Besides this there is a third sort of particles of matter, more solid, or else of form more adapted to motion: of this planets and comets are composed. There are three classes of celestial heavens: the first, that of our sun and its system; the second, the various heavens of the fixed stars immediately adjoining; the third, including all which are beyond, and which never can be seen in this life. The *primary* particles, as those are called which are obtained by attrition from the secondary particles, at last become more than enough to fill the intervening spaces (how this could be Descartes does not say), and the residue, as fast as it arises, was forced to the centres of the vortices, where it formed certain very fluid spherical bodies: these are the sun and fixed stars. The secondary particles receded from the centres to make room. The efflux of these primary particles from the fluid bodies just described is light. The centrifugal force of particles in motion round a centre is then dwelt on, and the circular form of the sun and fixed stars is attributed to it. The motion of the vortices must be such that their contiguous parts may have a common motion. The primary particles flow from the poles of each vortex towards the centre, and from the centre towards the other parts. But the same must not be said of the secondary or spherical particles (the reasons given are fanciful in the extreme, consisting entirely in different motive powers given to the two species of particles).

The preceding may give a sufficient idea of the sort of foundation which Descartes builds upon, and his manner of raising the structure. He proceeds through what he supposes to be explanations of all the phenomena of light, of the formation of planets and comets, and of all the varieties of conformation which are seen in the solar system. Why comets have tails and planets none; how the primary particles of other vortices find their way into ours, so that we can see the fixed stars; how the planets obtained their first motions of projection: how the spots on the sun are formed, and so on, are all explained by the powers of the two species of particles: an hypothesis on their nature being always ready when wanted. A reader who has looked into this book of Descartes's 'Principia' begins to understand two things better than before: first, the satire on philosophical explanations contained at the end of Molière's 'Malade Imaginaire,' written a few years after the death of Descartes; next, the declaration of Newton, *Hypotheses non fingo*.

As the hypothesis of vortices is usually represented, it has a certain reasonableness of appearance, which no doubt makes many wonder why it should be so universally contemned. If a fluid mass were whirled round the sun, it would carry the planets with it: and the supposition of minor vortices, one round each planet which has a satellite, is perfectly consistent with the laws of hydrostatics. When Newton proposed to refute the system of Descartes, he was obliged to have recourse to numerical considerations: he could not but admit that a planet, in one of Descartes's vortices, would have an orbit; but he showed, from the nature of fluid motion, that it could not have the orbit which, from the time of Kepler, it was known to have. The quality of a phenomenon is known before its amount is measured; and it is natural to expect, in the history of philosophy, that explanations which serve to account for the nature of a phenomenon, but are irreconcilable with its amount, should precede those which are drawn from consideration of both. The possibility of the planetary motions finding their proximate cause in the rotation of a fluid mass which fills the solar system, is a thing which did suggest itself, and ought to have suggested itself, to the inquirers of the time which elapsed between Copernicus and Newton. Descartes says expressly, "putandum est, non tantum Solis et Fixarum, sed totius etiam cœli materiam fluidam esse: *quod jam vulgo omnes astronomi concedunt*, quia vident phænomena planetarum vix aliter posse explicari." No mechanical difficulty stood in the way in their time; and those who had seen particles of dust whirled about by the air would have no difficulty in imagining the hypothesis of a vortex. Now we find this fault with the common notion of Descartes's system: the disparagement which belongs to it *as a whole*—to the primary and secondary particles which, though obtained from the same original particles, yet have different laws of motion, and to the gratuitous deduction of everything from this fancy—is conveyed to their readers by writers who only present the most rational extract which could be made, namely, the idea of a vortex. This is the sort of syllogism on which such writers proceed: "Descartes's system is ridiculous; all I know of that system is its vortices; therefore I must laugh at the vortices." Yet not only was Newton obliged to have recourse to his most powerful weapons to refute these vortices, but it is not at all a settled point that his refutation is sound; that is, his mathematical refutation. His remark that comets could not find their way through the vortex is much more to the purpose, though Descartes has his way out of this difficulty, as out of every other.

VORTICES. [VORTEX.]

VOUSSOIR, one of the stones of an arch. [ARCH.]

VOW (from the Latin "votum," through the French), a promise to perform some future act, or to pursue some future line of conduct, confirmed by an appeal to the Supreme Being, or at least to some supernatural power, to punish or be propitious to the maker of the promise according as he breaks or keeps his word. Abraham made his steward swear that he would faithfully discharge the mission to seek out a wife for Isaac; this is an example of the vow which is supposed to bind a man to perform one definite act or incur some supernatural punishment; and the oath taken by witnesses, in courts of justice, at the present day, to speak the truth, belongs to the same class. [OATH.] Some vows again are understood to bind those who make them to the performance of certain limited duties for the whole of their future life—such are the marriage vow, as contemplated by the Church of Rome and the law of England, and the coronation oaths of kings. Some vows are even intended to give a particular form and direction to the whole of a man's future emotions, thoughts, and actions—such are the priestly and monastic vows. The view entertained of the character and operation of a vow has differed materially at different periods. The vow originated in a religious conception, in the recognition of some unseen power superior to and exercising a control over visible nature and man's destinies. But as the moral faculties of society expanded, the vow came to be regarded as a solemn form of making a promise, in which the appeal to the Divinity was meant to remind the utterer of the oath of what men are too apt to forget, that the eye of God was upon him, and that His universal and unfailing law punishes crime and falsehood. The operation of a vow is different upon two different classes of minds. To the ignorant and superstitious it affords a motive (their fears) for adhering to a course of action that their fickleness or dishonesty might have tempted them to swerve from. In the more enlightened it awakens a stronger sense of the importance of the act they are about to undertake, renders them more cautious to pledge themselves beforehand, more resolute in performing a promise once made.

The instances in which, in a rude state of society, advantages are derived from vows or promissory oaths, are perhaps not few in number, but they are still exceptional. The bad influence of the superstitious view of the nature of a vow is permanent: it perverts men's moral opinions by leading them to regard actions as vicious and virtuous, not because of their own inherent character, but because of their being consistent or inconsistent with a promise made beforehand. Men have thus been led to see criminality in the non-performance of a crime they had pledged themselves to commit. The danger with regard to vows, understood in the more rational sense, consists in their too frequent use, or in their employment upon trivial occasions. The public promise of a king ascending the throne to govern with equity—the pledge of man and wife to know one undivided interest till death—the promise to give true and faithful evidence where the property, life, or honour of a fellow-being are at stake—are worthily and usefully accompanied by an appeal to the Divinity, that reminds the makers of these promises of the importance of the engagement they have taken upon them, and brings the religious sentiment to strengthen and confirm the dictates of expediency. But custom-house oaths, masonic vows, and such trivialities and mummeries, degrade the vow to the level of a mere theatrical show, or of the thoughtless habit of interjectional swearing in common discourse. The addition of a vow does not render a promise more binding, or alter the reason why it is binding. A promise affords a ground of belief that a man will act in a certain pre-determined manner, instead of being carried away by the whim of the moment. It is of advantage to the individual who makes promises that he should, except in extreme cases, contract the habit of adhering to them, because it imparts consistency and power to his character; and it is of advantage to all with whom he may have dealings that he should contract this habit, for it renders their transactions with him safe. Hence the universal feeling that, except in very extreme cases, promises ought to be kept, even to the maker's disadvantage. Vows are exactly on the same footing: the superadded appeal to the Divinity by its solemnity renders men more cautious in binding themselves, and more earnest and unwavering in the performance of their promise. The danger of making vows frequently and on trivial occasions has been inferred from the nature of the religious sentiment called into play: a further restriction of their admissibility may be deduced from he nature of the simple promise. It limits man's freedom of action, and so far is a disadvantage. It ought to be confined to actions: for a man to pledge himself to feel and think only in a certain manner is to undertake an impossibility. It pledges him to an unhealthy struggle against the order of nature. The promise ought moreover to be restricted to actions meritorious in themselves, and of some consequence. If to commit a crime is bad, to promise to commit one, and deliberately to keep the promise when aware of the criminality of the act, is worse. To tie a man's self up by a promise from the commission of an action indifferent in itself is a wilful waste of the power of self-denial, of which man at the best has no more than barely serves his necessities: the mind worn out with struggling against harmless propensities falls an easy prey to temptation in more important matters. The whole history of the monastic orders, a history attractive from the grandeur of its irregular and imaginative struggles, is an illustration of these views. With regard to simple promises, the rule of action is to make as few as possible, and exert every effort to keep them unless convinced that to do so would be a crime. With regard to vows, the same rule holds if possible with more force, because fickleness in regard to them implies a profane trifling with the most sublime emotions of our nature.

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* The matter in the space about a planet, or star, which is under the influence of that planet, is called its *heaven*.

VOWEL. [ALPHABET.]

VOYAGE. [SHIPS; BOTTOMRY.]

VULCAN. [HEPHÆSTUS.]

VULCANISED INDIA RUBBER. [CAOUTCHOUC MANUFACTURE.]

VULGATE. The Vulgate (*Vulgata versio*), or common version, is the name sometimes given by St. Jerome to what he elsewhere calls the *Vetus*, or ancient version, and what St. Augustine calls the *Vetus Itala*, or Old Italian Version, being the most generally received of those early Latin translations of the Scriptures distinguished by biblical critics as the ante-Hieronymian, all which are now lost, with the exception of some parts of this *Vetus Itala*, and such fragments of the others as are quoted in the writings of the Fathers. Jerome's first labours as a translator of the Scriptures consisted in a revision and correction of this original Vulgate, which he completed about A.D. 390. Before this date, however, he had commenced an entirely new translation from the original Greek and Hebrew; and it is this to which the name of the Vulgate is now given. The earlier Vulgate, as revised by Jerome, has all perished, except only the Book of Psalms and the Book of Job, and the apocryphal Books of Maccabees, Baruch, Ecclesiasticus, and Wisdom. The use of Jerome's new version appears to have been gradually introduced; but ever since the 7th century, when it was sanctioned by Pope Gregory I., it has been exclusively adopted by the Romish Church. The Council of Trent, in the 16th century, even conferred upon it an authority superior to that of the original text, by ordaining that "the Vulgate alone should be esteemed authentic in the public reading of the Scriptures, in disputations, in preaching, and in expounding, and that no one should dare to reject it under any pretext whatever." Accordingly, all the Romish translations of the Bible into the modern languages profess to have been made not from the Greek and Hebrew, but from the Vulgate.

The true text of Jerome's version, however, has been at all times matter of doubt and controversy. It very early got mixed with that of the *Vetus Itala*; and the restoration of its purity employed the labours of Alcuin, by direction of Charlemagne, towards the close of the 8th century, of Lanfranc, archbishop of Canterbury, in the 11th, of Cardinal Nicholas and others in the 12th and 13th. After the invention of printing, the Latin Bible was the first considerable work that was sent to the press; but the earliest editions exhibited a very corrupt text. The first critical editions were those produced at Paris by Robert Stephens (Etienne), in 1528, 1532, 1534, 1540, 1545, and 1546. Of these the edition of 1540 is accounted the best. Other corrected editions are those of John Hentenius, a divine of Louvain, first printed at Louvain, in folio, in 1547, reprinted by the Plantins, at Antwerp, in 5 vols. 8vo, 1565 and 1574; and that of Lucas Brugensis, and other divines of Louvain, printed at Louvain, in 3 vols. 8vo, in 1573; and again, both in 8vo and 4to, in 1586.

The first revised edition of the Vulgate promulgated by authority in the Romish Church was issued at Rome from the press of the Vatican, in three volumes, folio, in 1590, under the title of 'Biblia Sacra Latina, Vulgatæ editionis, jussu Sixti V. recognita et edita.' This edition, the preparation of which had been begun under Pius IV., was declared by Pope Sixtus to be the authentic text, and is known as the Sixtine Vulgate, or the Bible of Sixtus V. Yet it had been no sooner published than it was discovered to be full of misprints and other errors, which were very insufficiently corrected by the necessary emendations, printed upon separate strips of paper, being here and there stuck over the original word where the passage had been most grossly disfigured. Gregory XIV., who succeeded Sixtus V., ordered it to be suppressed, and the true Sixtine Vulgate is now of excessive rarity. A new edition of it, in the same form, was brought out in 1592, under the authority of Gregory's successor, Clement VIII., and this is called the Clementine Vulgate, or more frequently by Roman Catholic writers the corrected Bible of Sixtus V. It is now the authorised edition in the Romish Church; the Vulgate as since printed being commonly entitled 'Biblia Sacra Latina, Vulgatæ editionis Sixti V. et Clementis VIII.' Protestant controversialists have, naturally enough, made the most of the variations to be found between the Sixtine and Clementine Vulgates, each published and declared to be the only true edition by an authority professing to be infallible.

VULPE'CULA ET ANSER (the Fox and the Goose), a constellation of Hevelius, situated immediately above Aquila and Sagitta. It does not contain any stars of conspicuous magnitude.

VULPINIC ACID. [LICHENS, COLOURING MATTERS OF.]

W

W is a letter which performs the double office of a consonant and a vowel, the natural order of the vowels being *i*, *e*, *a*, *o*, *u*. The sounds then of *i*, that is *ee*, and *u*, that is *oo*, are the most remote, and the attempt to pass with rapidity from either of these to the others, more particularly to the other extreme, gives an initial breathing which has the character of a consonant, namely, in the one case *ee-oo*, or *you*; in the other *oo-ee*, or *we*. Hence it is that the letters *y* and *w* appear as the representatives, sometimes of a consonant, sometimes of a vowel. The English character *w* is formed by the repetition of a *v*, which itself is only a variety of the symbol *u*, and that again has in all probability grown out of the letter *o*. [ALPHABET.] The Anglo-Saxon alphabet employs the symbol ƿ. In Latin the *v* or *u consonans* had probably the power of a *w*, a supposition which at once accounts for the use of a common character for the vowel and consonant. The Greek and Hebrew alphabets had also a single symbol for this consonant, which occupied the sixth place, and is called digamma in the former, *vau* or *waf* in the latter. But in the Greek alphabet the letter went out of use, and is, therefore, commonly omitted in our grammars of that language, although the gap at this point in the alphabetical designation of numbers still bears evidence to the original position of the letter. [DIGAMMA.] Most of the modern languages of Europe are deficient in a symbol for this letter. The French employ what is a sufficient though a clumsy equivalent, the diphthong *ou* prefixed to a vowel, as in the common particle *oui*; the Spaniards prefer *hu*, as in *huevo*, *hueso*. In this way the map of the New World often gives testimony as to the race of Europeans who originally settled in the country. Thus the Indian tribe which has furnished a name to the territory belonging to the United States now called Wisconsin, in the old maps is written Ouisconsin, that country having been first visited by the French. So again in Mexico, the town Chihuahua (pronounced Chiwáwa) tells us that its name was first written by Spaniards; and the same may be said in the map of Peru of the river Huallaga; and the numerous towns commencing with the same syllable, as Huancavelica, Huancayo, Huanuco, Huancabamba, &c. At other times the Spaniards have employed the letters *gu*, as may be seen in the different rivers of Spain Proper, which have prefixed the Arabic word *guad*, denoting water; and this mode too of representing a *w* is to be traced in Spanish America in Guamanga, Guanca, Guancarama, Guatemala, &c. The ancient Greeks again often prefixed a simple *o* to represent a *w*, as in *οιδα*, &c. [DIGAMMA.] We have hitherto spoken of the consonantal power of the letter; its use as a vowel, so far as our own language is concerned, is confined to the end of syllables; and there is always another vowel prefixed to it, as in *new*, *law*, *show*; but in the Welsh language it is employed by itself, and in the middle of syllables with the power of a vowel. The map of Wales will furnish abundant examples, as Pwlheli, Cwmtydr, Bettws, Llwchwr, often written Loughor, &c.

Many nations have a difficulty in pronouncing the consonantal *w*. This is more particularly the case in some parts of Germany, where the people are unable to appreciate the difference between a *w* and a *v*, almost always substituting the latter sound, or what nearly approaches to it. Hence it is important for the philologist to distrust the evidence and criticism of a German scholar when these sounds are in question; and this caution may be more particularly given in reference to German writings upon the Sanskrit language. London too is remarkable for the confusion of the sounds, though this confusion does not seem to arise from any inability to pronounce either a *w* or a *v*, each being substituted for the other with a most amusing perversity.

The other interchanges of this letter have been already given under the preceding letters. See C, § 4 and 7; G, § 6; H, § 7; M, § 5; O, § 11; R, § 8; S, § 11; and DIGAMMA.

WAFER, a small round piece of dried paste, which is used to fasten letters. The host, as given to laymen at the sacrament in the Romish Church, and the piece of consecrated cake given in extreme unction, is also called a wafer, and it is recommended to be swallowed whole if possible. Thin cake formed into a roll, and called wafers, is still sold by pastrycooks. In fact the word was used in England to signify a thin cake long before wafers for sealing letters were invented.

Waffel is the name given by the Germans to a thin cake made with flour, eggs, sugar, &c.; the Dutch call such a cake *wafel*, and the Danes *vaffel*. The French call it *gaufre*. The French name for a wafer is *pain à cacheter*, and wafers are *pains à cacheter*. The Anglo-Saxons also had the name *waffel*.

To make common wafers, a liquid paste is made with flour and cold water, very smooth; and colouring matter is then mixed with it. The baking is done with an instrument similar to that which is used to make *gaufres* and *waffeln*. It consists of two thin plates of iron; the upper plate closes upon the lower, which is made with a ledge, and thus forms a mould for the paste. Both plates having been warmed and greased to prevent adhesion, some of the liquid paste is poured into the lower plate, and the upper plate is then shut down, which forces out any superfluous paste and forms the rest into a thin and even layer. The instrument which is held by a handle like that of a frying-pan, is placed for a few moments over a fire, and the sheet of baked paste is then taken out and dried in the air, when it becomes firm and brittle, and is cut with a suitable instrument into wafers.

Gelatine or *transparent wafers* are thus made. Good gelatine or glue is dissolved in warm water. The mixture, while still warm, is poured on a warm and slightly oiled glass plate, having a bordering formed of slips of cardboard; another warm plate is laid on it, and pressed. When cold, the gelatine is removed in a very thin, semi-transparent sheet, and is cut into small pieces of the proper shape by means of a punch. Sometimes a little sugar is added to the gelatine.

Medallion wafers have a device in cameo or relief. The device is first engraved in intaglio on a metal plate. A paste is then made of any convenient powder mixed with gum-water or size; a background is formed of melted coloured gelatine; and the two are so applied to the engraving as to lead to the production of a sheet of medallion wafers, which are separated by cutting or punching.

WAGER. In a wager or bet, two parties stake money against each other on the happening or failure of a certain event: A is to pay a certain sum to B if the event happen one way; and B is to pay a certain sum to A if the event happen the other way. Thus, if John bet Thomas three to one (in pounds) that he will win the game, and it turn out that he does win the game, he (John) is to receive one pound from Thomas; but if John should not win the game, Thomas is to receive three pounds from John.

The principle of a wager exists in a great multitude of transactions which do not bear the name: in fact, every commercial affair in which money is risked upon a possibility of receiving more than legal interest in consideration of that risk, is a wager. Thus, if John lend Thomas 100*l.* to engage in an adventure, knowing that he can receive nothing if it fail, and in consideration of 150*l.* if it succeed, it is a wager of the following kind. If the money be out a year, and John could safely make five per cent. of it, he risks 105*l.* in case of loss, and is to receive 45*l.* in that of gain; so that in fact it is as if John bet Thomas 105 to 45, that the speculation would succeed. For if we were to suppose that John lends Thomas 100*l.* for a year at five per cent., on good security, and makes the above wager besides, they will be found to be in exactly the position originally described.

A fire insurance is a simple wager between the office and the party; and a life assurance is a collection of wagers. There is something of the principle of a wager in every transaction in which the results of a future event are to bring gain or loss. And in every game of chance, we have a wager or a collection of wagers, whenever money is staked.

Much has been written and said upon the morality of wagers, in which the word is understood in its common acceptation, namely, that there is nothing but a stake of money, made in a manner which has no reference to commercial advantage, and no tendency to promote the physical well-being of the community. It is however exceedingly difficult to draw the line between the pure wager, which is nothing else, and the commercial wager. The loan of John to Thomas, above described, may be a useful transaction: it may give the country a new mine or a new market. But it does not follow that the pure wager, or a case which is generally so considered, may not be also useful. It were to be wished that, in considering this matter, the right and wrong of the transaction itself should be always carefully separated from the tendency of the collateral circumstances connected with it. One or two instances will explain our meaning.

A horse-racer and a stock-jobber are two of the characters which are set down in public opinion as mere gamblers, and so are a billiard-player and a hazard-player. All four are considered to belong to the same class. Now it is true that the occupations of all but the second are generally connected with much that is objectionable, and which, though not necessarily attached to their mode of life, are so frequently consequent upon it, that the strength of the tendency is sufficient to justify the warning which writers upon morals give against the pursuit of gambling. And among all the four descriptions of characters are to be found the full proportion of those whose society is not coveted by a very respectable minority of the nation. But though many a man born to better things has been ruined by each of the four pursuits, it would be unjust to say that there is no distinction between them. We doubt whether billiards or hazard ever were the cause of any benefit to society; the wager which ends in a wager seems to be the proper description of both. But horse-racing has at least improved the breed of horses; and, as business is now transacted, it is due to the stock-jobber that funded property can be turned into money, or *vice versâ*, at any moment of the year. We do not mean to say that the money which changes hands on the course might not be much more effectively employed in the improvement of horses, or that it might not be practicable to effect modes of rapidly realising or investing without the concomitant of gambling. All we wish to illustrate is the fact, that innumerable classes of wagers are mixed up with the transactions of society, from those which are essential to its existence, through those which are of mixed harm and good, up to those which are but dubious in their very best cases.

A wager is fairly laid when the odds are proportional to the probabilities of the event happening or failing. Thus if it be four to one against the happening of an event, the better who bets that it will not happen should offer four to one. In the long run such an event will fail four times where it happens once, and the better will receive a pound four times for every occasion on which he pays four pounds once. But suppose a person should continually offer only three to one upon a contingency on which it is four to one he wins. In the long run he will, upon every five bets, receive one pound four times, and pay three pounds once: he will therefore win one pound on every five bets. Algebraically thus:—let the odds for his winning be a to b, while these which he offers are m to n; in $a+b$ trials, one set with another, he will win n pounds a times, or £na, while he will lose m pounds b times, or £mb. If na equals mb, the wager is fair on both sides; if na be greater than mb, it is unduly favourable to the better; if na be less than mb, it is unduly against him.

There are many cases in which doubt may arise as to whether a wager is fair, and also as to how it is to be interpreted. With respect to the latter it is or ought to be clear, that if both parties understood the wager in one sense, that one sense is the fair interpretation: but that if either of the parties understood the wager in one certain sense, and the other party knew that he understood it in that sense, no subsequent attempt at a different interpretation should be admitted on the part of that other party. We are told that this rule is widely departed from; and that under cover of adherence to literal signification of words, interpretations are permitted which offer inducements to what we must call attempts at fraud. Thus, it is said, that when the better undertook to run across a bridge in an incredibly small time, and had his bet accepted, he was permitted to win by running from one parapet to the other, which was held to be crossing the bridge, in the same manner as going from one footpath to the other is held to be crossing a street. Here it is clear that the party accepting the bet understood that the other was to cross the water upon the bridge, which is the true meaning of going across a bridge; and it is also clear that the better knew he was taken in that sense. An adherence to the literal meaning of a wager is, of course, necessary in all cases of doubtful meaning, but there is no language in which the literal meaning of a sentence is always made up of those of the words put together.

A wager is not fair unless the point in doubt be clearly the same to both parties, and unless there be no concealed knowledge in the possession of either. The latter is included in the former, as an instance will show. John bets Thomas that the ship Hope is arrived in dock from Jamaica before the time at which the bet is laid; his manner implies that he has formed the conclusion from his knowledge of the time at which the Hope was to sail, of the properties of the vessel, of the prevailing weather, &c.: if his manner tell truth, the wager is fair Or his manner implies that he may be in possession of particular information, that he may have seen the captain, &c.; it says, "Mind, I do not tell you what my reasons are, all I tell you is the fact:" still the wager is fair. If Thomas dispute, he knows in either case what he disputes, be it the question of the Hope's rate of sailing, or the goodness of John's inference from his particular knowledge. But if John, actually knowing of the Hope's arrival, should lead Thomas into a wager on the probabilities of the ship having arrived, when he knows that it actually has arrived, the wager is unfair. In all matters of skill, indeed, the mere offer of the wager is an assertion of skill, and the acceptance of the wager is the denial of this assertion: this is understood, so that there is no occasion for the party who offers the wager to make any declaration of skill, other than is implied in the wager itself.

There is one case, and that a common one, in which the immorality of the wager is not easy to expose, though it is, we think, sufficiently certain; it is where a person, by offering different wagers to different people, secures himself a certainty of gain, let the event happen which way it will. Thus one of three things must happen, A, B, C; a person bets 4 to 4 against A, 5 to 4 against B, 6 to 4 against C, with three different persons; he must win 8, for two of his opponents must lose: he cannot pay more than 6, for one only can win; he is therefore, on the most unfavourable supposition, a gainer of 2. As against each of his opponents the wager may be fair: these may not be known to each other, and each one may consider that he has the best of the wager. Whom then does he injure? If it be admitted that a man has a right to lay any bet which he can get taken provided the event betted on be perfectly understood, he can then injure no one, and no exception can be taken to the proceeding. But if it be not allowed that a man has a right to lay any odds, except those which, to the best of his knowledge and belief, represent the state of the chances, he must then offer a bet which he believes to be unfair, to some one or other of the preceding persons. By betting 4 to 4 against A, he declares his belief that the chance of A's arrival is $\frac{1}{2}$: similarly by betting 5 to 4 against B, he declares his belief that the chance of B's arrival is $\frac{4}{9}$. Consequently he implies a declaration that his belief of the chance of C's arrival is—

$$1-\frac{1}{2}-\frac{4}{9} \text{ or } \frac{1}{18}.$$

Consequently he ought to lay 17 to 1 against the arrival of C, whereas he lays 3 to 2, or 6 to 4. He is then telling contradictory stories to different people, and is saved from conviction only by the fact of each party not knowing what he has stated to others. If there were a possible mode of fighting in which the weapon of each opponent should be armour against those of the rest, we imagine it would not be considered either brave or honest that a man should provoke the combat with several enemies, in such a manner that he should be sure to kill, and sure not to be killed; and we suppose that if wagering be permitted at all among men of honour, it is under the idea that he who makes another risk his money also risks his own.

This possibility of securing certain gain by betting against belief (for against belief it must be) seems to us to be enough, were there no other reason, to show that a wager is not right, unless the odds really represent the opinion of the better: for to maintain that such a wager is a fair one, is also to maintain that it is fair to make others meet risk without sharing it.

It may indeed be asserted that each better has his own book, which he endeavours to make up in such a way as to win in every event; so that the whole is an admitted trial of skill. But this excuse breaks down when it is remembered that it is impossible a society of gamblers can make a set of books which will give a balance of gain to all, without *taking in* a number of persons who do not belong to the society: and the question is whether the words in italics have not two real meanings.

WAGER (in Law.) [GAMING.]

WAGER OF BATTLE. [APPEAL; TRIAL.]

WAGER OF LAW was a mode of trial where the defendant was permitted, as it was said, "to make his law," that was, "to take an oath (for example) that he oweth not the debt demanded of him upon a simple contract, nor any penny thereof;" "but he ought to bring with him eleven persons of his neighbours that will avow upon their oath that in their consciences he saith truth; so that he himself must be sworn *de fidelitate*, and the eleven *de credulitate*." This form of trial was not allowed save when the debt arose by word only, and might have been satisfied in secret without witnesses. It was not permitted as to any debt arising on specialty, or where a contempt, trespass, deceit, or injury was supposed in the defendant; but only in some cases, in debt, detinue, or account; and also in a real action where the tenant alleged that he was not legally summoned. Neither was it permitted to an infant, nor to a person outlawed or infamous, nor in a suit on behalf of or for the benefit of the crown, nor to executors or administrators in matters relating to the debts of their testator. Where admitted, however, it was conclusive, and barred the party for ever. This mode of trial seems to have existed at a very early period in the history of nations. It was part of the law of Moses, that "If a man deliver unto his neighbour an ass, or an ox, or a sheep, or any beast to keep, and it die, or be hurt, or driven away, no man seeing it; then shall an oath of the Lord be between them both, that he hath not put his hand unto his neighbour's goods, and the owner of it shall accept thereof, and he shall not make it good." (Exod., xx. 10.) The practice of trying by the oaths of the parties to a suit prevailed in the civil law, where either of the parties might refer the matter to the oath of his adversary; and if he did not accept it, or justify his refusal of it, the judge decided against him. The whole proceeding is prescribed at length in 'Cod. Justin.,' iv. 1, 12. The clergy, also, in the earlier ages were generally admitted to this mode of defence. It was also one of the customs of London in the sheriffs' court. But in this country it ultimately gave dissatisfaction. "Men's consciences," as Lord Coke says, "grew so large," that the presumption of law that no man would forswear himself ceased to be much relied on. Other forms of actions were brought, such as assumpsit and trover, in which the wager of law could not be had; and eventually, by 3 & 4 Wm. IV., c. 42, s. 83, the whole proceeding was abolished.

WAGER-POLICY is a name given to a policy of insurance made by persons having no interest in the event about which they insure. Such insurances, formerly common, were found to be "productive of many pernicious practices," and therefore the statute 19 Geo. II., c. 37, was passed, by which it was enacted that no assurances should be made on any ship belonging to his Majesty or any of his subjects, or on any goods, &c., laden on board, "interest or no interest, or without further proof of interest than the policy, or by way of gaming or wagering, or without benefit of salvage to the assurer; and that every such assurance shall be null and void to all intents and purposes."

WAGES are the price paid for labour. The labour of man, being an object of purchase and sale, has, like other commodities, a natural or cost price, and a market price. Its natural price is that which suffices to maintain the labourer and his family, and to perpetuate the race of labourers. The rate of wages cannot be permanently below this natural price, for if in any country labourers could not be maintained, they must cease to exist: they must be exterminated by famine, or be removed to some other country. If the price paid were only sufficient to maintain the labourer himself, without any family, he would be unable to marry, or his children would die of want. By these distressing causes the supply of labour would be reduced until the competition of employers had raised the price of labour to its natural level. But although the natural price would thus appear to be that which only wards off starvation, there is, happily for mankind, a principle which tends to raise it to a much higher standard. Every man desires to improve his condition, to enjoy more of the comforts and luxuries of life than have fallen to his lot, and to raise himself in the estimation of others. If he has accomplished this, he acquires habits of living which it is painful for him to forego. He endeavours to bring up his children with the same views and habits as his own, and feels it a degradation if they fall below the standard which he has himself attained. The necessary consequence of this tendency to social improvement is to cause prudence and forethought in marrying, and undertaking the support and settlement of a family. A labourer cannot well have too many wants. He should desire good food, good clothing, a cleanly and comfortable home, and education for his children. If the standard of wants could be universally raised, the natural price of labour would rise in proportion; for if each labourer were determined not to render himself unable to gratify these wants, all could command the wages that would supply them. The degree in which this principle operates determines the natural rate of wages and the condition of the working classes. Where it has no influence, as in many parts of Asia, the wages are only sufficient to support life upon the commonest food, and to provide the most squalid clothing and habitations. In more civilised countries, the wants and prudence of the middle classes extend lower in the scale of society, and the labourers want more and enjoy more of the comforts and decencies of life.

The general market-rate of wages depends upon the ratio which the capital applied to the employment of labour bears to the number of labourers. If that ratio be great, the competition of capitalists must raise wages; if small, the competition of labourers amongst each other, for employment, must reduce them. Whenever the accumulation of capital is proceeding more rapidly than the increase of population, wages will be on the increase, and the condition of the working classes will be continually improving, until some check has been given to the increase of capital, or until the growth of population (which is naturally encouraged by high wages) has altered the relative proportion of capital to labourers, and reduced the market-rate of wages to the natural rate. While the general rate of wages is regulated by these causes, there are various circumstances which, by increasing or decreasing competition for employment, tend to raise or depress the wages paid to persons engaged in particular occupations. Some of the principal of these are—

1. The agreeableness or disagreeableness of the employments.
2. The easiness or cheapness, or the difficulty and expense, of learning them.
3. Their constancy or inconstancy.
4. The small or great trust that must be reposed in those who carry them on.
5. The probability or improbability of succeeding in them.

It is not uncommon to hear these circumstances stated as the direct and immediate causes of high or low wages in particular employments; as if in some cases employers voluntarily gave high wages, or the labourer could command them merely on account of the nature of the employment. But the relation of supply to demand will influence wages in particular employments, as it does the price of labour generally, and of other commodities; and the circumstances stated above will obviously tend to increase or diminish the number of competitors for particular employments. More will naturally seek an agreeable trade, easily learned, than one of a disagreeable character and difficult to learn. All descriptions of skilled labour bear a higher price than unskilled labour. The expense of acquiring the knowledge of any art or trade would not be incurred at all, unless the person who had incurred it were better remunerated than others who have nothing to offer except their natural strength and intelligence, which is common to all men; but many cannot incur the expense of learning a trade if they would; others are too indolent, too careless, or too awkward; and thus skilled workmen are not open to the same unlimited competition as other classes of labourers, and are in a condition to command higher wages. Wherever uncommon skill, talent, or other advantages are required, the number of persons actually practising and living by an employment must be comparatively limited. Most persons are deterred from attempting to learn it by the fear of failure, and many who attempt it do not succeed in gaining their livelihood by it. The few who are really successful can then command an extraordinary reward for the exercise of their peculiar talents or acquirements. The world will enjoy the advantage of them at any price, not being satisfied with any less degree of excellence. Even if an unusual influx of skilled labourers into any employment should lower the rate of wages, this lower rate is not likely to continue very long, as the superfluous number would seek other employments which offered a higher reward. This result is facilitated by the fact, that the ordinarily high price of skilled labour causes a much more expensive mode of living, and thus raises the natural rate of wages of skilled labourers; or, in other words, induces them to regard as necessaries a variety of comforts which are beyond the reach of common workmen.

Wages are usually calculated in money, and are called high or low according to the money price actually paid; but the condition of the labourer is obviously affected by the price of commodities as well as by the amount of his wages. If the necessaries of life be cheap, low money wages will maintain him in comfort; if they become dearer, higher wages will not improve his condition, but will leave him as he was. Hence it becomes a most important object to inquire whether the price of provisions affects the rate of wages. The disputes which have arisen upon this question would seem to be chiefly caused by attempts to apply a universal law to countries and employments under totally different circumstances. Some contend that as wages are regulated by supply and demand, the price of provisions cannot affect them; while others maintain that the average prices of labour and of food must always, for long periods of years, conform one with the other. It is evident, at the outset, that the former are speaking of the market rate of wages, and the latter of the natural rate; and if this distinction be borne in mind, the two propositions may easily be reconciled. If the market rate of wages be high, it is because the demand for labour is greater than the immediate supply. A fall in the price of provisions could not then lower the rate of wages, because the supply of labour would still be the same; but if the fall were permanent, the condition of the labourer would become so easy, that population would increase, and the supply of labour would be more abundant. The market rate would thus be brought down to the natural rate, unless capital should be increasing in the same proportion as the supply of labour; and any increase in the price of food must then check the growth of population, limit the supply of labour, and ultimately raise wages. There is the same tendency in the market price of labour to conform to the natural price as there is in the market price of commodities to conform to their real value. Both labour and commodities are equally capable of increase and diminution, and the varying causes which encourage or check production adjust the proportion between the natural or cost price and the market price. But in some countries the market rate of wages may be very much above the natural rate, and in others nearly the same. In one country capital may be increasing more rapidly than population, and in another not so fast. It is clear that a rise or fall in the price of food cannot influence the rate of wages alike in all these countries. Where the wages are high, and capital is rapidly accumulated, any reduction in the price of food and other commodities is a clear gain to the labourer, and can have only a very remote, if any, effect in lowering wages; but where wages are already reduced to the natural rate, and capital is not increasing faster than population, wages will undoubtedly rise and fall with any permanent increase or diminution in the cost of subsistence.

The question is further affected by the differences which exist in the natural rate of wages in various countries. Where the natural rate is so low as only to afford the bare means of existence, the least rise in the price of food must be fatal to numbers of the labouring population, and, by thus limiting the supply of labour, must raise its price; but where the natural rate is high, the labourers suffer indeed from a rise in the price of food, but their existence is not endangered, the supply of labour is not diminished, and their wages consequently do not rise. From these circumstances, it is evident that the precise condition of a country in respect to capital, population, and wages must be ascertained before it can be determined whether the price of food will affect the money rate of wages. It may, however, be generally affirmed, that in proportion as the market rate approaches to the natural rate, and the latter to the mere cost of the commonest subsistence, will the price of the necessaries of life affect the rate of wages.

When the causes which regulate the price of labour are understood, the folly and injustice of any legislation to fix the rate of wages are obvious. The seller of an article will always endeavour to obtain a high price for it, which the purchaser will only give if he be unable to obtain it for less. Labour is the most important object that man has to buy or to sell. Each will make the best bargain he can, and in this no law ought to restrain him. Laws may purpose to affect wages either directly or indirectly. Direct interference with the rate of wages has been frequently resorted to. By several acts of parliament a legal rate of wages in particular employments was ordered to be settled, from which any deviations either on the part of the employer or labourer were punishable. (See 25 Edw. III., stat. 1; 34 Edw. III., c. 11; 13 Rich. II., c. 8; 11 Hen. VII., c. 22; 5 Eliz., c. 4; 1 James I., c. 6.) Unless all the causes of high or low wages already explained be visionary, it is plain that no law can overrule them and establish a legal rate different from that which natural causes would have produced. It may embarrass the operations of trade, and mischievously disturb the freedom of the labour market; but it cannot attain its immediate end—a compulsory rate of wages. The experience of this fact has long since put an end to any such legislation in this country. The most pernicious interference with wages ever effected by the indirect operation of a law resulted from the mode of administering the laws for the relief of the poor. Before these laws were altered in 1834, it was the practice in most parishes, especially in the south of England, to give relief from the poor-rate to labourers in proportion to the number of their children. The natural rate of wages was continually undergoing depression, because, marriages being encouraged without reference to the sufficiency of wages to support a family, population was extraordinarily promoted. At the same time, the property destined to support it was suffering diminution, by being taxed heavily for the payment of comparatively unproductive labour.

The only sound mode of raising wages and improving the condition of a people is to promote and encourage the increase of the general wealth of a country [WEALTH], by every means which legislative science points out as best suited to that end, and at the same time to remove obstructions, and give facilities to the moral and intellectual improvement of the working classes. By these means capital will be increasing with the natural growth of population; while the labourers, with better habits, will be less prone to reckless improvidence, and consequently not so likely to outrun the increase of capital.

It is not unusual for persons in particular employments to desire higher wages, and to enter into combinations against their masters in order to obtain them. Such combinations were formerly prohibited both by the common and statute law of this country; but since the 5th Geo. IV., c. 95, if unattended with violence or intimidation, they are not unlawful. Unless he has bound himself by a contract, every man has a right to give or withhold his own labour as he pleases; but he has no right to prevent others from disposing of their labour. But the only mode of rendering a combination effectual is to exclude fresh workmen, which frequently can only be done by molestation and threats, which are subversive of the freedom and peace of society. Strikes, temperately conducted, cannot in principle be condemned, being often a necessary protection to the working classes. When masters are not dealing fairly with their workmen, the fear of a strike may often control them, especially as, when acting unjustly, they would find a difficulty in obtaining new hands. But where the cause of a strike or combination is not an occasional dispute concerning wages, but an attempt to limit the number of workmen by compulsory regulations and bye-laws, and to dictate to their employers, it is injurious to trade, and ultimately to the parties themselves. To the labouring classes at large such combinations cannot be beneficial. Whenever they are successful it is by excluding many competitors, who are, of course, injured by the exclusion. The labour market must become clogged by a mass of exclusive trades, which render it difficult to find employment. The injury suffered by trade in consequence of the artificial limits to the supply of labour and the unnaturally high wages must also have the effect of diminishing capital, and consequently the means of employing labour.

(Adam Smith's *Wealth of Nations*; Ricardo's *Political Economy and Taxation*; Malthus, *Essay on Population*; Mill, J., *Elements of Political Economy*; Mill, J. S., *Principles of Political Economy*.)

WAHHABIS or **WAHABEES**, is the name of the adherents of a Mohammedan sect in Arabia. The origin of this sect is intimately connected with the following circumstances. When Sultan Selim I. had conquered Egypt and deposed the last khalif of Cairo, Al-mutawakkel in A.H. 922 (A.D. 1517), he was acknowledged as successor of the khalifs by Berekiat, the grand sherif of Mecca, who presented him with the keys of the Ka'bah. From this time the sultans of the Osmanlis were the protectors of the Mohammedan faith, though only recognised as such by the Sunnites; they were the guardians of the holy cities, Mecca and Medina; and they had the privilege and the duty of protecting the numerous caravans of hájís, or pilgrims, which annually travel to Mecca. A Turkish pasha resided at Jidda, and sometimes also at Mocha, and while the fertile provinces of Hejaz and Yemen in Western Arabia seemed to obey the Sultan, the pashas of Baghdád and Basrah made frequent attempts to establish the Turkish authority in the province of El-Hassa in Eastern Arabia. The Mohammedan religion had generally departed from its primitive purity, and was particularly corrupted among the Turks. The Mohammedans had introduced novelties into their religion, which were rather calculated to please the senses. and which found favour among people who have always loved to follow the bent of their imaginations. Mohammed gradually received honours like God himself; virtuous men became saints, and the miracles they were said to have performed were eagerly believed by the people; many austere rules of the Korán were forgotten or left to the extravagances "of a few derwishes and fakirs;" and the places of worship were adorned by the princes and the rich with the arts and luxuries of the East, while the poorer Mohammedans indulged their passion for religious buildings by erecting a rude tomb to some unknown saint, surmounted by a cupola of painted brickwork. To this we must add that the Korán ceased to be the sole source of religious knowledge, and that traditions concerning Mohammed were considered by his disciples as pure and trustworthy as the Korán itself. Although the Arabs had deviated from the rule of the Korán, there was a striking difference between them and the Turks. The Turks used opium and wine; not satisfied with polygamy, they had intercourse with prostitutes; they were addicted to practices against nature, which are strictly prohibited by the Korán, and more than once holy hájís of the Turkish caravans had polluted the sacred cities with their scandalous conduct. The caravans especially, those congregations of pious men assembled for the purpose of performing one of the most sacred duties of their faith, presented a revolting aspect to the simple and uncorrupted believers among the Beduins of the desert. Their leaders gave full licence to debauchery, and although it was generally their riches which tempted the Beduins, and excited them to predatory attacks, it often happened that the Son of the Desert unsheathed his sword indignant at the pride and vices of men who, from the moment they reached Mecca, proudly assumed the holy title of *hájí*.

Such was the state of the Islám, when, in the beginning of the last century, a Mohammedan sheikh conceived the project of reforming the religion of Mohammed, and restoring it to its primitive purity.

This sheikh was 'Abdu-l-Wahháb ("the servant of Him who gives (us) every thing"), who was born at El-Hauta, a village five or six days' journey south of Der'aiyeh, the capital of the province of Nejd, on the road from this town to the district called Wádi Dowásir, or as some say at 'Al-Aynah, in Nejd, or Aiyineh, which seems to be El-Ayeyneh, near Der'aiyeh. 'Abdu-l-Wahháb was born at the beginning of the 12th century of the Hijira, which corresponds to the end of the 17th century of our æra. His father was the sheikh, or chief, of the Benī Wahháb, a branch of the great tribe of Temím, which occupies a considerable part of Nejd. 'Abdu-l-Wahháb received his education in the schools of Basrah, where he studied divinity. He made the usual pilgrimages to Mecca and Medina, and lived several years at Damascus, where he had frequent disputations with the divines on religion, but displaying great zeal in the abolition of abuses, his doctrine was considered as schismatic, and being exposed to persecutions, he fled to Mosul. After some time he returned to Arabia, but the doctrines which he preached to the natives, and his violent attacks on Turkish tyranny and vice, became so many causes for new persecutions, and he led a wandering life till he settled at Der'aiyeh, the residence of the sheikh Mohammed Ibn Sa'úd. This intelligent chief listened to the words of the reformer. He became his disciple; he married his daughter; and soon drew his sword to propagate the new doctrine among the tribes of Arabia. Mohammed Ibn Sa'úd thus laid the foundations of a powerful empire on theocratical principles, of which his descendants remained masters for nearly a century.

When Sa'úd, the grandson of Mohammed Ibn Sa'úd, conquered Mecca, he ordered a kind of confession of faith to be published, the substance of which is as follows:—

'Abdu-l-Wahháb's doctrine teaches the salvation of mankind. It is divided into three parts: I., the knowledge of God; II., the knowledge of religion; III., the knowledge of the prophet. In the first part, God, it is said, is one Almighty, and we acquire the knowledge of him by adoring him. The second part, knowledge of religion, is threefold, and contains—1. The Islám, or resignation to the will of God; 2. Faith; 3. Good works. The Islám contains five things: 1. The belief that there is only one God, and that Mohammed is his prophet; 2. The five daily prayers; 3. Alms, one-fifth of the annual income; 4. Fasts during the month of Ramazan; 5. The pilgrimage to Mecca. The Faith contains six things, namely: 1. The belief in God; 2. In his angels; 3. In his Holy Scriptures; 4. In his prophets; 5. In his divine and perfect qualities; 6. In the day of judgment. Good Works are only the consequence of the rule that we should adore God as if he were present to our eyes; and though we cannot see him, we must know that he sees us. The knowledge of the prophet, which is the most important part of Wahhábism, is based on very positive principles. Mohammed, the prophet, was a mortal like all other men, and he preached for all the nations of the world, and not for one only, the Arabs; no religion is perfect and true in all its parts except his, and after him no other prophet will come; Moses and Jesus were virtuous men, though inferior to Mohammed, notwithstanding he was not of divine nature. Those who do not fulfil their religious duties are to be severely punished. The reformed religion shall be propagated with the sword, and all those who refuse to adopt it are to be exterminated. 'Abdu-l-Wahháb not only forbade the adoration of Mohammed and of saints, but he also ordered their splendid tombs to be destroyed, and he declared tradition to be an impure source. He made several other prohibitions concerning social and religious abuses, such as the habit of using wine, opium, and tobacco, the use of the rosary for prayers and he preached strongly against those unnatural practices which were and are still so frequent among the Turks.

The doctrine of 'Abdu-l-Wahháb was no new religion: it was Mohammedanism reduced to a pure deism, and so little did it deviate from the Korán, that even to the present day many theologians of Syria and Egypt do not venture to say that it is schismatic. Yet this reformer maintained that there had never been any man directly inspired by God, and that there was no scripture or book whatsoever which was entitled to be called divine. Hence it follows that according to 'Abdu-l-Wahháb there is no revealed religion; and if he calls the Mohammedan a divine religion, it is not because he believed that it had been transmitted directly from God to man, but merely on the ground of its perfection.

The reformed Mohammedanism made rapid progress, especially among the nomadic Arabs, or Beduins, who had never adored Mohammed as a divine person, nor viewed the Korán as a divine book, although they considered themselves to be as orthodox Mohammedans as any of the other nations which have adopted the Islám.

The inhabitants of the towns were less inclined to adopt Wahhábism, but Mohammed Ibn Sa'úd nevertheless succeeded in conquering the greater part of Nejd, of which he was the temporal chief, while 'Abdu-l-Wahháb was the spiritual chief. The system of government established by these two men was strictly conformable to the political prescriptions of the Korán, and very like that of the first khalifs. The chief authority lay in the hands of the temporal chief, but this authority was confined to the direction of important affairs; the governors of the provinces and the under-governors were kept in strict obedience to the orders of the prince, but their authority over the Arabs was not very great. The ulema of the capital, Der'aiyeh, who generally belonged to the clan or family of Sa'úd, formed a council or ministry for religious and legislative affairs, and in time of war the governors used to assemble in Der'aiyeh for the purpose of concerting the plan of the campaign. Trade and agriculture were well protected. The revenues of the Wahhábí empire were composed of:—1. One-fifth of the booty taken from heretics; the four remaining fifths were for the soldiers. 2. The tribute, called "alms" in the Korán: it was a certain part of the property, which varied according to the nature of the property: for fields watered by rain or rivers it was one-tenth of the yearly produce; for fields watered artificially, one-twentieth only; merchants paid one and a half per cent of their capital. The Beduins, who had always been tax-free, disliked these "alms" very much, but they were indemnified by the frequent occasions of plunder. 3. Revenue from the chief's or prince's own estates, and from the plunder of rebellious towns. The punishment for a first rebellion was a general plunder, one-fifth of which belonged to the fiscus; in case of a second rebellion, all the grounds belonging to the town were confiscated, and became the property of the reigning chief; and as such rebellions were very frequent, the chief acquired immense estates. The greater part of them were afterwards confiscated by Mehemet 'Ali, the pasha of Egypt. Except a few hundred men who formed the prince's life-guard at Der'aiyeh, the Wahhábís had no standing army, but assembled when the prince designed some expedition. Two or three great expeditions were made every year.

The name of the Wahhábís soon became known in the Turkish provinces adjacent to Arabia. The Turkish government was not aware that this sect had as much warlike and religious energy as the Arabs under the first khalifs, and employed little activity in their efforts to coerce them. The Wahhábís were successful in their resistance. They gained several battles, and even possessed themselves of Mecca. At length their subjugation was entrusted to Mehemet 'Ali. [MEHEMET 'ALI, in BIOG. DIV.] He commenced his preparations in 1809, but active hostilities only began in 1811, and continued for several years. By 1818, however, their power was completely broken, and 'Abdullah, the successor of Sa'úd, was captured, sent to Constantinople, and there beheaded. The sect, however, though subdued, was not exterminated. They have more than once risen again in arms, but have been repressed; but still their tenets are understood to have numerous adherents throughout Arabia.

(Burckhardt, *Notes on the Bedouins and Wáhabys*; Mengin, *Histoire sommaire de l'Egypte sous le Gouvernement de Mohammed Aly*; Corancez, *Histoire des Wahabis*.)

WAHLENBERGIA, a genus of plants belonging to the natural order *Campanulaceæ*, of which the botanical characters are given in the NAT. HIST. DIV. To this genus belongs the Wall Pellitory of Great Britain; and some of the numerous foreign species are cultivated on account of their blue and red flowers. For this purpose the seeds of those which are annual should be sown on the hot-bed, and when the plants are of sufficient size they may be placed out in the open border in a warm sheltered situation in the month of May. The hardy perennial species may be grown in pots in a mixture of peat and loam, and should be kept rather moist. They are easily increased by division.

WAIF. If the goods of any person were stolen, and the felon, thinking that pursuit was made after him, fled, and during his flight waived or abandoned the goods, they became waif, and were forfeited to the crown, or to the lord of the manor, if he were entitled to waif. No goods could become waif which were not in possession of the felon at the time of his flight. Therefore, if he concealed the goods, or placed them in a house, or, for instance, left a horse at an inn in pledge for his meat, and afterwards fled, the goods did not become waif.

It was necessary, in order to complete the title of the crown or lord of the manor to waif, that it should be taken possession of by some one on his behalf; otherwise the original owner was not barred from recovering his goods at any period of time, and if he seized them first, they remained his property. The forfeiture of goods waived was instituted for the purpose of stimulating the person robbed to make fresh pursuit after the felon, and so, if possible, catch him with the goods upon him. And in further encouragement of such pursuit, it was part of the law, that if the owner succeeded, within a year and a day, in attainting the thief, he was entitled again to recover his goods from the crown or the lord of the manor, even though they had been reduced into possession. The restriction of the character of waif to goods waived during the flight was because goods which had been concealed by the felon would afford no track of his course, and might very possibly escape the search of the owner, even though he did make fresh pursuit. It is said also that the goods of foreign merchants could not become the subject of waif, because a foreigner, ignorant of our language and usages, could not be expected to act with the same despatch and effect as a native. Lord Coke distinguishes between waif which was stolen property, and the goods which were the property of a person who fled for a felony. These latter were always forfeited on proof and finding by a jury of that fact, even though the party were acquitted of the felony. Part of the inquiry, therefore, on the trial of a prisoner for felony, was whether or not he fled for it. If the jury found that he did, his goods were forfeited, whatever might be the verdict as to his guilt. This was either because of the presumption which his flight raised, that he really had committed the offence, though it could not be legally proved against him; or, according to Mr. Justice Foster, because his flight tended to stop or embarrass the course of justice against the real offender. If he was killed during his flight, the coroner's jury inquired as to his flight as well as respecting the cause of his death. By 7 & 8 Geo. IV., c. 29, s. 57, the court before whom a prisoner is convicted has power in all cases, without restriction as to time, to order restitution of stolen property to the owner, except as to negotiable instruments in the hands of parties who, without notice, have given value for them: and by 7 & 8 Geo. IV., c. 28, s. 5, the jury are no longer to be charged to inquire whether a prisoner fled for treason or felony. The consequence is that no forfeiture can now be incurred by such flight.

(5 Co. 109; Com. *Dig.* tit. 'Waife.')

WAIN, CHARLES'S. [Ursa Major.]

WAITS is a name now applied only to those itinerant musicians who, in most of the large towns of England, especially London, go round the principal streets at night for some time before Christmas, play two or three tunes, call the hour, then remove to a suitable distance, where they go through the same ceremony, and so on till four or five o'clock in the morning.

The word, which was formerly spelled *wayghte* or *waighte*, is common to all the Teutonic languages (German, *wacht;* Dutch, *wagt;* Danish, *vaght;* Swedish, *wakt;*) and the root is the same as the Anglo-Saxon *weccan*, to wake, and *wacian* (pronounced wakian), to watch, and the English *wake* and *watch*.

The wayghte, or wayte, was originally a minstrel watchman, and the kings of England, as well as the mayors of large corporate cities and towns, seem to have employed them in preference to common watchmen. By a document in Rymer's 'Fœdera,' vol. ix., "De Minstriellis propter Solatium Regis providendis," it appears that in the reign of Edward IV., "a wayte that nightelye from Mychelmas to Shreve Thorsday pipethe the watche within this courte fower tymes, in the somere nyghtes three times, and make the bon gayte at every chambere doare, and office, as well as for feare of pyckeres and pillers; he eateth in the halle with the mynstrielles;" it then goes on to state his allowance of bread, ale, coals, and so forth, for each night.

The waits seem to have been always distinct from the common watch, which was called the marching watch, and never, we believe, the waits. At a later period, the term waits seems to have been restricted to the band of minstrels kept by the city of London and other large cities and towns. We read of the City waits frequently, from their attendance on the City pageants, and of the waits of Southwark and other places. In 'The Tatler,' No. 222, a writer from Nottingham complains that the young men of fashion there "make love with the town music," and that "the waits often help him through his courtship." The waits, or stipendiary town-musicians, have for many years, we believe, ceased to exist in every corporate city and town in England, though there are yet town-bands, who, at least in some cases, are stipendiary musicians.

(Brand's *Popular Antiquities*, by Ellis; Strutt's *Sports and Pastimes*, by Hone.)

WAIWODE. [Waywode.]

WAKES, holiday festivals which are kept once a year in some of the rural districts of England. They are the remains of certain religious wakes, wakings, or vigils, followed by a festival, which were once held in all the country parishes. Previous to the Reformation in England, every church, when it was consecrated, was dedicated to some particular saint or martyr, and every rural parish had its wake every year, and most of them had two wakes, one on the day of dedication, the *dies dedicationis*, and another on the birth-day of the saint, the *propria festivitas sancti*. These church festivals seem to have been established by the early popes and bishops soon after the introduction of Christianity into England, in the place of the heathen festivals to which the people had been accustomed.

In the Saxon times the church method of reckoning the day was from sunset to sunset, so that the Sunday and festival and fast days began about six o'clock on the evening preceding the day itself, and the eve was in fact the commencement of the sacred day, when the people were accustomed to repair to the church and to join in the religious exercises. These night devotions were called in Anglo-Saxon *wæccah*, wakes, and the night itself was called the eve (the Anglo-Saxon *æfyn*, or *æven*), which explains why Christmas-eve and other eves of sacred days precede the day itself. On these occasions the floor of the church was strewed with rushes and sweet-smelling herbs [Rush-bearing], the altar and pulpit were adorned with green boughs and flowers, and tents were erected in the churchyard, which were supplied with provisions and ale. The eve was dedicated to devotion; the following day to festivity. These festivals gradually deviated in most parishes from the original purposes for which they were instituted. The inhabitants of neighbouring parishes attended each other's festivals, and others came from a distance, especially if the saint was of high reputation; hawkers and pedlars frequented them with their wares, and the religious wakes were converted into fairs and scenes of dissolute indulgence. The wakes continued to be kept in this way till 1536, when Henry VIII., by an act of convocation, ordered the festival of the saint's day to be abolished, and that of the dedication of the church to be kept on the first Sunday in October in all the parishes. But the saint's day was the favourite festival of the people; they gradually ceased to attend the festival of the dedication, and it has long been entirely discontinued, while the saint's day festival still subsists in the altered form of a country wake.

(Strutt's *Sports and Pastimes*, by Hone; Brand's *Popular Antiquities*, by Ellis.)

WALES, PRINCE OF, is the title usually borne by the eldest son, or heir apparent, of the British king or queen. This title originally distinguished the native princes of Wales; but after the entire conquest of Wales and its union with England, the title was transferred to the sons of the kings of England. Henry III., in the 39th year of his reign, gave to his son Edward (afterwards Edward I.) the principality of Wales and earldom of Chester, but rather as an office of trust and government than as a special title for the heir apparent to his crown. There is a tradition that Edward, when he became king, to satisfy the national feelings of the Welsh people, promised to give them a prince without blemish on his honour, a Welshman by birth, and one who could not speak a word of English. In order to fulfil his promise literally, he had sent his queen, Eleanor, to be confined at Carnarvon Castle, and he invested with the principality her son, Edward of Carnarvon, then an infant, and caused the barons and great men to do him homage. Edward was not at that time the king's eldest son, but on the death of his brother Alphonso he became heir apparent, and from that time the title of Prince of Wales has ever been borne by the eldest son of the king. The title, however, is not inherited, but is conferred by special creation and investiture; and has not always been given immediately after the birth of the heir apparent. Edward II. did not create his son Prince of Wales till he was ten years old, and Edward the Black Prince was not created until he was about thirteen.

The eldest son of the king is by inheritance Duke of Cornwall. Edward the Black Prince was first created duke of Cornwall on the death of John of Eltham, his uncle, who was the last earl of Cornwall; and by the grant under which the title was then conferred, in the 11th Edward III., the dukedom is inherited by the eldest living son and heir apparent. If the duke succeed to the crown, the duchy vests in his eldest son and heir apparent; but if there be no eldest son the dukedom remains with the king, the heir presumptive being in no case entitled to it. The Black Prince was also created by his father earl of Chester and Flint. By the statute 21 Richard II., c. 9, the earldom of Chester was erected into a principality, and it was at the same time enacted that it should be given only to the king's eldest son. Although that statute, with all the others in that parliament, was repealed by the 1st Henry IV., c. 3, the earldom has ever since been given together with the principality of Wales.

The antiquity of the title of Prince of Wales and its regular succession are, as it were, a confirmation of the parent's present right and of the prince's own nearness in succession to the crown. Thus on the death of Edward the Black Prince, Edward III. immediately made his grandson Prince of Wales. Richard III., as soon as he came to the throne, created his son Prince of Wales, in order to strengthen his usurpation. Henry VII., again, on the death of his son Arthur, created his next son, Henry, Prince of Wales. Henry VIII., having no son, created his daughter Mary, Princess of Wales; and after her illegitimation, his next daughter, Elizabeth. Each of them in succession had only been heiress presumptive, yet they bore the title, being then next in succession to the crown.

The titles now borne by the eldest son of the sovereign as heir of the crowns of England and Scotland, are "Prince of Wales and Earl of Chester, Duke of Cornwall and Rothsay, Earl of Carrick, Baron of Renfrew, Lord of the Isles, Great Steward of Scotland."

(Selden's *Titles of Honour*, part ii. c. 5; Connack's *Account of the Princes of Wales*, 8vo. 1751.)

WALKING-WHEEL. A mechanical contrivance by means of which the dead weight of men, or animals, acting upon one side of a wheel by walking upwards, is made to act as the motive power of the machine to which it is applied. It is frequently used in quarrying operations, or in agricultural districts, where labour is cheap; but in large towns it is rarely the case that the wheel-cranes can be advantageously employed, because in those localities artificial sources of power, or the more complicated adaptations of machinery, are found to be more economical than the employment of the dead weight of human beings. The walking-wheels were, however, much used in engineering and architecture in the last century, and they are retained at the present day in the quarries around Paris; but the tendency of modern practice is unquestionably to lead to their abandonment in favour of more perfect mechanical contrivances.

The walking-wheel used by Peyronnet at the bridge of Orleans is a good illustration of this class of engines. It consisted of an upright post, or pivot, supported by a strong framework of timber, bearing, upon a metal pivot at its head, an inclined beam, projecting on one side to form the arm of the pulley, and on the other to support the windlass and the walking-wheel. The weights upon either side of the pivot were arranged in such wise that they balanced one another as nearly as possible when the machine was in work; and the motion was given by the movement of the men walking in the interior of the wheel. The power exercised, therefore, in these engines depends upon the ratio of the radius of the men's path to the radius of the axle, and upon the weight of the men employed; and as in quarrying operations it is possible to increase the diameter of the walking-wheels to almost any dimension which may be desired, they are usually made of great size. Peyronnet made his wheels about 12 feet 9 inches in diameter; near Paris they are sometimes made of from 16 feet to 18 feet in diameter. Generally speaking the men walk on the inside of the wheel; but occasionally they tread upon, and hold by, rounds placed upon the periphery of the wheel; in either case it is essential to provide means by which the motion should be regulated and the men may be prevented from making false steps. If the load at the extremity of the arm should at any time, for instance, exceed the weight of the counterbalancing machinery, there would be a danger of its overpowering the men and of causing the wheel to run backwards; the consequences of such an accident would be, in all probability, fatal to the men employed; and it is therefore essential to bear in mind that the useful range of the use of walking-cranes must be limited to the narrow bounds of the weights on the respective sides of the machinery. Walking-wheels are seldom used, even in rude districts, when the weight to be raised exceeds four tons.

Animal power is occasionally applied to walking-wheels by making horses, donkeys, and even dogs, move in them; but all these animals exercise so much greater power when pulling against a collar in a horizontal direction, that they are more commonly and more advantageously employed in horizontal mills than in the vertical walking-wheels. The old-fashioned turnspit wheels formerly in use in mediæval kitchens afford familiar illustrations of this class of machinery.

The tread-wheels used for the punishment of offenders are, in fact, walking-wheels; but in them the wheels are designedly so balanced that the mere weight of the prisoners placed upon the boards causes the wheels to revolve, and thus to bring in succession the various boards under the feet of the men, who are compelled to tread upon each of these boards, unless they prefer receiving very heavy and painful blows. No use is made of the power thus exerted, and it seems to be one of the most painful considerations connected with this mode of punishment, that the men feel and know that they are working in vain.

(Peyronnet, *Nouvel Architecture Hydraulique*; Borgnis, *Traité complet de Mécanique*.)

WALNUT, ECONOMICAL USES OF. The walnut tree, though not so valuable as many other trees growing in this country, subserves a great number of useful purposes. The majority of timber trees do not yield fruit palatable to man; the majority of fruit trees do not yield timber of any considerable size; but the walnut yields both.

Walnut-wood is white in young trees; but in the older varieties, the wood is solid, compact, veined, and of a brownish colour, slightly shaded with lighter brown and black. It was the wood most highly valued for the best kinds of furniture before the introduction of mahogany; and many old mansions contain fine specimens of the work thus produced, exhibiting great beauty of grain, polish, and pattern. Walnut-wood is found very useful for press screws, wooden shoes, clogs, musical instruments, gun-stocks, turnery ware, coach-making, wheel-making. It is preferred to all other kinds of wood for the stocks of muskets and rifles: in 1806 no less than 12,000 walnut trees were required for musket-stocks for the British army; this led to a great rise in price, which in its turn led to a great increase in the planting of walnut trees in England.

Of the use of the fruit of the walnut as food, little need be said here. In some countries the nuts are regarded as a food, in others as a luxury. In a young and green state the whole fruit is pickled, the pulpy husk as well as the undeveloped nut or kernel. Besides the pickling, the French adopt a mode of preserving the green fruit; they also make a prepared dish from the very young kernels, and a *conserve brûlée* of kernels in a dried state. Large quantities of walnut oil are obtained from the fruit. The fruit is gathered, the husk removed, and the kernels are kept dry throughout the winter. The mucilage has by that time been converted into oil. The nuts are cracked with a small mallet; the fragments of hard shell are carefully removed, and the soft kernels are crushed under a millstone into a kind of oily paste. This paste is put into strong linen bags and pressed; the best walnut oil is obtained from it. The residue is taken from the bags, moistened with warm water, heated in a copper, replaced in the bags and pressed a second time; oil of an inferior quality is thus obtained. Walnut oil, largely made in France and Italy, is used as a substitute for olive oil at the table, for almond oil in medicine, and for whale oil in lamps. Artists employ it in the preparation of white and delicate colours, on account of its limpidity and quick drying. It is used in France as an ingredient in copper-plate printing ink; and some authorities state that the backs of prints for which this kind of ink has been employed do not turn yellow so quickly as under the influence of the ordinary English ink. The *marc*, or oil-cake, remaining from the oil-pressure, is used in some country districts as a material for candles, and in more as a fattening diet for sheep, swine, and poultry. The husks of the unripe fruit readily yield a dark dye—a fact rendered evident by the state of the hands of walnut-peelers. Sometimes the flooring of rooms is dyed to a dark colour, by boiling walnut husks to a paste, strewing this paste in a layer on the floor, and allowing it so to remain till dry.

The walnut tree in spring will yield, by incision of the trunk, a sap, which in some parts of Asia is evaporated into a cheap substitute for sugar; and a kind of wine may also be distilled from it. A liquor, obtained by boiling the roots of the tree before the rising of the sap, is used as a brown dye for the face by gypsies and theatrical performers. The leaves, and the bark of the young shoots, may in like manner be made to yield a brown dye.

Considered in reference to fuel, walnut-wood ranks almost on a level with sycamore; it burns with a violet flame. It does not take a high rank as a material for charcoal. Potash may be obtained by burning the leaves. Nearly all parts of the tree—the fruit, the bark, the root, the wood, the sap—have been brought into requisition for medicinal purposes.

WALTZ (from *Walzen*, Germ. *to roll*), a gay dance, in triple time, and executed by two persons, who almost embracing, rapidly turn round on an axis of their own, while moving quickly in a circle whose radius is from ten to twelve feet, according to the dimensions of the room.

WAPENTAKE (from the Saxon *waepen*, arms, and *tac*, touch, or *betach*, yield) is a term which prevails in Yorkshire, and indicates a territorial division like the hundred of other counties. [SHIRE.] The word is derived from the habit which our Saxon ancestors had of attending with their weapons the meetings of their tribes, whether convened for the administration of justice or to decide on peace or war. This circumstance, inseparable from the assembly, gave a name to the meeting and to the district whose inhabitants were convened. Various explanations, all however connected with this habit, are given to the last syllable. By some it is supposed to mean the *touch* or rustling of their arms, by which the assembly was wont to signify its opinion of the matters submitted to it; by others the *acceptance* by the lord of his tenants' arms in token of their submission to him. These are the two solutions quoted by Spelman. Others, however, say that the word denotes the custom which the vassals had of *touching* the spear of the lord as a mark of homage; and this seems to be the explanation most usually adopted. (Spelman, *Wapentachium et Wæpengetachium*; Cowell.)

WAR, SCIENCE OF. The science of war has been divided by military writers into Strategy and Tactics, and sometimes into Grand and Elementary Tactics. Under STRATEGY and TACTICS we have defined what are the limits of those divisions, and given the general principles which govern strategic operations; as also some of the principal definitions, such as Base of Operations, Lines of Operations, Interior Lines, &c. It is, therefore, unnecessary to recur to these further than to recapitulate the main principles which are or should be the basis of all military operations, and which, though often neglected when stated, appear self-evident truisms. These general principles are: to bring the mass of the forces successively into collision with portions of the enemy; to operate as much as possible on his communications without exposing your own; and, thirdly, with a view of being superior at the point of collision, to act on *interior* lines. [STRATEGY.] These principles must be borne in mind in making all military combinations, whether for a campaign or on the day of battle; and such combinations will be more or less good as these principles are more or less carried out.

In Europe, an army while in the field can draw much of its support from the country in which it is acting, and therefore it does not wholly depend upon its magazines for its means of subsistence; yet even in this part of the world the supplies of provision and forage which can be obtained in an enemy's country are often precarious, and an army without regular communication with its depôts is in danger of being reduced to the necessity of surrendering in order to avoid being starved. Such a disaster is still more likely to overtake an army in the East, if unprovided with the means of support in itself, since there the military force of the enemy consists largely in swarms of light cavalry, who, avoiding regular engagements, hang continually upon the flanks and rear of the army, both preventing supplies from arriving and cutting off all parties who may be beyond the protection of the main body. In fact, an army is in all cases dependent on its communications with its depôts and base of operations for receiving its supplies, not only of provisions, but also of ammunition and reinforcements, and also in getting rid of its sick and wounded. And, further, such is the moral or psychical effect on an armyof its communications being interrupted, that it has always been held by the greatest generals, not only of our own time, but of antiquity, that such an event is the sure prelude to disorganisation and defeat. Now a base of operations may be a single fortress or sea-port town; but, as a general rule, it is a long strip of country, and in this latter case a slight consideration of its object and of the general principles which should guide all military combinations indicate what is the best form for a base of operations, namely, that it should form two sides of an angle approaching more or less to a right angle, so situated with respect to the theatre of war that one side is parallel and the other perpendicular to the enemy's base of operations. For it is evident that, supposing the enemy to have advanced into the theatre of war, a great power of acting on his communications is afforded by employing the end of the most advanced portion of the rectangular base for entering the theatre of war; for it places the army on the enemy's communications in his rear without at the same time exposing its own. It is not necessary that the base should be right-angled to give this advantage; for, in fact, a base of any other form is good when, by projecting into the theatre of war, it gives the power more or less of acting from an advanced point on the communications of the enemy. Napoleon's theatre of war at the commencement of the Austerlitz campaign was bounded on the north by the Mayn and northern boundary of the Austrian dominions, on the west by the Rhine and western boundary of Piedmont, on the south by the Gulf of Genoa, Romania, and the Adriatic and Illyria. The base formed by the Rhine and the Mayn, supposing the country north of the Mayn to be in possession of the French, is a base of the best kind. The Rhine is parallel and the Mayn at right angles to the Austrian base. Supposing, then, an Austrian army to advance into the theatre of war west of Bamberg, the French, advancing from Bamberg and Bareith, would cut off their communications, that is, their supplies of all descriptions, and in case of defeat, which is therefore probable, their lines of retreat, and, driving them into the angle between the Mayn and Rhine, utterly destroy them, while at the same time the communications of the French would be secure, and they could receive supplies and reinforcements, and, if defeated,—which, with these advantages in their favour, would not be probable,—they might with ease retreat into some fortified portion of their base of operations.

Again, the campaign of Moreau, in 1800, is a good example of a base of this kind, the base being formed by the High Rhine and the Lake of Constance and the line of the Lower Rhine, the French being in possession of Switzerland. Napoleon wished Moreau to pass the Rhine at Schauffhausen with his whole army, and thus to cut Kray off. As he had a *tête-de-pont* at Bâle, however, he was content with making certain of a lesser success, and, ordering Lecourbe to pass at Schauffhausen, he himself, with half the army, crossed at Bâle, effected a junction at Enghen, and occupied Stockhack, which was a very important point on the Austrian line of retreat. Kray, finding himself cut off in the angle of the high and low Rhine, with 60,000 men, endeavoured to retreat, but was met by Moreau and defeated at Enghen.

If we consider Spain roughly as a rectangle, three of the sides of which are formed by the sea and in possession of the English, whilst the fourth is in possession of the French, it will be seen what immense advantage the maritime base of Torres Vedras, at the extremity of one of the sides, conferred.

Lines of operations, as has been before stated, should at all times be interior [STRATEGY], so that the portions of an army moving on them may at any time be massed in superior numbers to the enemy at any point where a collision may occur; but at the same time a single road or strategic line, or indeed a single line of operations, may often be unfavourable, as it does not give so great security against the enterprises of the enemy, and in the presence of the enemy is extremely bad, as it necessitates the column being of great length on the line of march, rendering it unwieldy and liable to be overwhelmed by an attack in front, or cut in half at the same time. Lines at a distance from one another are objectionable, in so far as they may become exterior, and the troops on them be attacked in detail and overwhelmed before they can support each other. When it is said that a commander should always endeavour to operate on interior, and make the enemy operate on exterior, lines of operations, it must be understood that mere distance apart on the map is not the only criterion of lines being exterior or interior. Lines which appear exterior from their distance apart on the map may be really interior from their advantage of cross roads, &c., and more especially from the superiority in the rate of marching of the army moving on them. There is always an immense advantage in maintaining as large a strategical front as possible, for by so doing the enemy is kept in doubt and suspense as to the point on which it is intended to strike a decisive blow; but the length of this strategical point must of course be limited by the necessity of maintaining interior lines. Superiority in the rate of marching is then of immense importance. The divisions of an army which can march twice as fast as another are on interior lines, when 80 or 90 miles apart, to their enemy, when his divisions are 50 miles apart.

Napoleon said that if two armies are equal in all things except numbers and the rate of marching, the relative values of the two armies will not be found by comparing their numbers, but by comparing the products of their numbers and rates.

These considerations will show the immense superiority some rapid means of transit along the strategic front may give; for instance, a railway. It was by availing himself of a railway in this manner, that the Emperor Louis Napoleon made that splendid movement at the commencement of the late Italian war, when, by suddenly concentrating his forces, which had been extended along the whole line of the Ticino, on his extreme left, he crossed, and attacking the Austrian army before it could concentrate, won the battle of Magenta.

With respect to converging and diverging lines of operations. Diverging, or, as they are sometimes called, excentric lines, proceeding from any one point or more in a base, may perhaps occasionally be found advantageous for offensive operations, since by them bodies of troops may be rapidly moved up at once to different points in an enemy's line, and, if compelled to retreat from such points, they will gradually approach each other, and be able to unite at some point in their rear; but they are only admissible when the marches have been so ordered that interior strategical lines are observed, so that the divisions, by falling back or repassing the central point, may be in superior force at the point of collision. It is evident, therefore, that such lines should not have a great degree of divergence, especially when there are few or no cross roads of communication, since then the columns in their advance may become so far separated as to be in danger of being cut off in detail.

Diverging or excentric lines of retreat are eminently wrong. As an instance may be given Wurmser's retreat before Bonaparte. Bonaparte having directed his whole force on one division, overthrew it at Trent; then getting in rear, and on the communications of the other division, destroyed it at Bassano and Mantua; he, Bonaparte himself, having by a concentric retreat just previously been enabled to beat Wurmser.

The retreat of the Russian armies in 1812, under Barclay de Tolli and Prince Bagration, before Napoleon, is an example of the great advantages of concentric retreats. Though Napoleon made repeated attempts to intercept them, he was unable to prevent their retiring on, and joining at, Smolensko, whence they retired on Moscow; and though they were beaten at Moskwa, the battle was not very decisive; and their armies, by keeping together, were enabled to menace Napoleon's communications. This, according to Jomini, was the commencement of Napoleon's disasters.

Concentric lines of retreat require care in using them, that the divisions joining do not get intermingled, which may lead to inextricable confusion and disaster, as was the case with the Prussians after Jena, by which they suffered a severe augmentation of their disasters. Lastly, when an army employs converging or concentric lines of operations, it is necessary to organise the marches so that the divisions may arrive at their place of assemblement before the enemy can reach it, so as to intercept and defeat the divisions separately.

In the campaign of 1809, the British and Spanish armies were compelled to act on what are called double excentric lines of operations; for Lord Wellington was on the line of the Tagus, having Lisbon for a base, while Venegas with a Spanish army was employed in La Mancha; and there were besides the forces in Gallicia and Leon. The armies, being thus separated from each other, were quite unable to co-operate for one object, even had the Spanish generals and armies been capable of executing any combined operations.

Having thus far slightly considered the main principles of strategy, which space only permits us to touch on, we must for a further elucidation of them refer our readers to the various works, such as Jomini's, on this subject; and we cannot recommend a better work than the 'Elementary Treatise on Strategy,' by Edward Yates, B.A., as an introduction to the works mentioned at the end of the article, and to general military history, by the close study of which alone can a clear knowledge of the principles of war be obtained in the cabinet, the full knowledge and power of applying which must be obtained by experience in the field. Yates's 'Elementary Treatise on Tactics' cannot be too strongly recommended as an introductory work to the study of the other branch of the science of war.

The manner of reconnoitring ground and performing the details of military manœuvres, has been described under RECONNAISANCE, and EVOLUTIONS, MILITARY. We will now proceed to a consideration of military positions and the principles of tactics with relation to the marches of armies, and the general movements on a field of battle and in a retreat.

Military positions are the sites occupied by armies either for the purpose of covering and defending certain tracts of country, or preparatory to the commencement of offensive operations against an enemy.

A position is considered as advantageously chosen when it is on elevated ground; when it is not commanded by eminences within the range of artillery; and when, from the existence of natural obstacles, as rivers or marshes, on the wings, it is incapable of being turned, that is, the enemy cannot, without making an extensive movement, get to the rear of the army by which the position is occupied. In the event of such points of support being wanting, the position, whether it be a plain or an eminence, should have its flanks protected by villages, or by redoubts raised for the purpose; for the flanks being the weakest points of the line, since the troops there are only defended by their own fire, they particularly require to be strengthened by the impediments of the ground, or by fortifications, in order that the enemy, in any attempt to turn the position, may be retarded till reinforcements can be brought up to oppose him.

The advantages possessed by an army on commanding ground consist in the troops being able to see the manœuvres of the enemy while their own are concealed; the fire, also, being directed downwards, is more effective than that of the enemy, which is made upwards from a lower level. The existence of woods or hollow ways in front of a position is considered as an unfavourable circumstance, since an enemy might there place divisions or parties for the purpose of attacking the line by surprise; but, on the other hand, a wood in the rear, if it should not be such as to create an impediment to the passage of the troops through it, might become advantageous in the event of a retreat, as it would afford a temporary cover for the retiring columns. A village or even a single building on the ground occupied by the army may become the key of the position; and, as frequently on the preservation of this point depends the possession of the field of battle, such point should be well supported by troops and artillery. At the battle of Corunna, in 1809, the village of Elvina was twice contested by the opposing armies; and on the field of Waterloo, the Château d' Hougoumont was the object about which the action raged with the greatest violence. The highest point of ground, particularly if near the lines of operation (the roads leading to the magazines), may also constitute the key, and it is usually strengthened by one or more redoubts. It would evidently be advantageous if such key were near the centre of the line, because, on any change in the disposition of the latter, the key might still be retained, and if the wings are separated from each other, it might prevent either of them from being cut off by the enemy; whereas, if situated at one extremity, it might, on a wheel of the army taking place, become so remote as to be incapable of being supported.

The elevated ground which constitutes the position should be able to contain all the troops who are to occupy it; but it should not much exceed the extent necessary for this purpose, lest, not being able to defend the whole, the army should be deprived of the advantages arising from a superiority of command, in consequence of the enemy gaining some part of the height.

However favourable a position may be with respect to the elevation of the ground, that circumstance will be of small value if the troops and artillery cannot be conveniently placed on it. It is indispensable that the ground afford ample room for the manœuvres of that species of troops in which the strength of the army chiefly lies; and at the same time it may be observed that, in making choice of a position, the ground in front should be as much as possible disadvantageous in that respect for the enemy. The Spanish general, Cuesta, is blamed for having, previously to the battle of Rio Seco, in 1808, placed his army in such a situation that the ground before it was in the highest degree favourable for the action of the French cavalry, which was particularly numerous. Artillery should always be placed where it can act with most effect; and when the ground occupied by an army presents alternately salient and retired points along the front of the line, the batteries should be placed at all such points. At the former, in order that the lines of fire may effectually command the approaches by which the enemy's columns may advance; and at the latter, that they may defend the descending ground immediately in front of the others. Infantry may occupy any kind of ground, but should, if possible, always form a close line. It is usually placed between the batteries; and, if exposed to a distant cannonade, the troops may be drawn up in a trench, the earth from which will serve to cover them, without preventing them from marching out in line to meet the enemy. Cavalry must be posted on a level plain, over which it may advance with regularity when a charge is to be made; if compelled to act on broken ground, it is formed in small detachments behind the infantry, through whose intervals it may pass at proper opportunities. It may be observed, that every disposition of an army for defence should correspond to that of the works which constitute a fortified place. The batteries at the advanced points of the line serve a purpose similar to that of the guns in the flanks of bastions; and the intermediate line of troops forms a sort of curtain.

In the choice of positions for offensive operations, such should be taken as have no rivers or broken ground in front since these would impede the contemplated movements towards the enemy: small inequalities, behind which infantry or cavalry may be concealed, are, however, advantageous, as they afford the means of occasionally making attacks by surprise. On the other hand, when an army is on the defensive, the front as well as the wings should be protected by every obstacle to the progress of the enemy which nature may present or art can devise; among those afforded by the latter may be mentioned the blocking up of roads by abatis or traverses; preparing countermines by which, on the enemy's advance, the roads may be destroyed; rendering fords impassable and even forming inundations by constructing dams across the streams. It should be observed, however, that when a defensive position is covered by a river, the line of troops should be at 800 or 1000 yards in rear of the latter, in order that sufficient space may be afforded for the troops to act against the enemy in the event of his forcing a passage across; and, in all cases, every obstacle in the way of a free communication within the position ought to be removed, that the troops may easily succour each other when attacked. Whatever be the nature of the obstacles opposed to the enemy, they should be within the range of the artillery of the line; and then the position may be considered as impregnable, since an enemy would find it scarcely possible either to form or deploy his columns of attack on broken ground and under a destructive cannonade. Good roads, on the other hand, should exist, or should be formed, in the rear, both to facilitate the arrival of supplies from the magazines or depôts, and to favour a retreat, should the latter step become necessary. An army always retires in disorder under the fire of the enemy, and its danger is greatly increased when the retrograde movement is embarrassed by walls, ravines, streams, or other impediments; the divisions then become separated from each other, and some of them are generally cut off by the enemy before they can be supported. It would be advantageous that the ground in rear should command that of the position itself; for then the army, in retreating, would obtain a superiority of elevation over the pursuing enemy; and it might even have an opportunity of renewing the action with a prospect of success.

A knowledge of the art of choosing military positions is an important qualification in the staff-officers of an army; and these officers should continually exercise themselves in forming correct judgments concerning the fitness of ground for such positions. They should be able to ascertain at once, by the eye, its extent and the stations it may afford for troops of the different arms, so that those of all kinds may act with the greatest effect and duly support each other; and, consequently, they should be able to determine the order of battle which is the most advantageous for the ground to be occupied. They are also to judge of the facilities which the roads may present for an advance or a retreat, or for the conveyance of supplies from the magazines; and, finally, of the obstacles which the ground in front may oppose to the movements of the enemy. The power of readily appreciating the character of ground in all these respects is what is called, by foreign writers, the military coup-d'œil; and this can only be acquired by a profound knowledge of the tactics of war, joined to much experience in the practice of executing military surveys, and of contemplating the appearance of ground from all possible points of view. These points being the supposed stations of the enemy, the staff-officer should accustom himself to observe from thence how the latter might make his attack; for then only can he judge in what manner an attack ought to be opposed; that is, what disposition of troops and artillery would be the most favourable for resisting it when made.

The main principles which have been laid down at the commencement of this article as the guides to the conduct of strategical operations, are equally the principles in tactical combinations; the following observations, then, are simply with a view of showing how these may be carried out.

Marches comprehend all the movements by which an army transports itself from one place to another: when they are made at the opening of a campaign, and at a considerable distance from the enemy, they are called *routes;* and on such an occasion the object generally is to invade a country, to seek subsistence, to surprise the enemy or force him to make counter-movements, in executing which he may be advantageously attacked. During a campaign, and in the enemy's sight, marches are made in order to attack some important position which he may occupy, or succour some post which he may threaten, or in order to fall back on the magazines of the army. At the end of a campaign an army marches to the quarters which it is to take up for the winter.

When an army already encamped in order of battle is to advance towards the ground directly before it, the march is said to be to the front; and if it is to proceed to ground on the right or left of the line, the movement is called a flank march. In the former case it would be advantageous if there were several roads nearly parallel to one another, and all tending to the position which is to be occupied; and it would even be proper, should there not already exist a sufficient number, to make such, by cutting through woods or walls, forming causeways over marshes, or bridges over streams. The army might then be divided into several short columns, so as to be able with facility, if suddenly attacked, to deploy into line at any moment either during the march or on arriving in the new position: the intervals between the lines of route should therefore be, as nearly as possible, equal to the extent which the columns moving in those lines would occupy when formed in order of battle. The advanced guard, consisting both of infantry and cavalry, may march before the head of the centre column at the distance of about a mile; and these troops should be accompanied by the pontoons and the sappers who are to remove the obstacles, or form the bridges. When the French army advanced into Russia in 1812, it marched in three great columns nearly abreast of each other: the centre column proceeded along the main road; and the country being one vast plain, the others with their artillery moved over the ground on both sides.

On a flank march along nearly parallel roads, since the heads and rears of the columns are where the extremities of the wings of the army would be if in order of battle, the several lines of route should be as near together as possible, that the troops may readily move into their proper places in re-forming the line; and it is obvious that, in such marches, the divisions in each column should be well closed together; for should they become separated by rivers, marshes, or any other obstacles, the enemy might seize the opportunity to attack a division before it could be supported by the others.

The difficulty of returning rapidly to the order of battle when attacked, is the reason that flank marches in the presence of an enemy are dangerous, particularly when the ground offers no impediment to his approach: they however become necessary when a position is to be taken up on either extremity of an enemy's line; and in order that they may be executed with safety, the columns should be protected in flank by a corps appointed for the purpose. In general an effort is made, by false demonstrations, to deceive the enemy, for a time at least, respecting such movements: these consist in opening roads in different directions through woods or enclosures, in laying bridges over streams, in sending provisions and stores, and even bodies of troops, to various points; and, while the enemy is in a state of uncertainty concerning the object of the demonstrations, the columns secretly commence their march: care however is to be taken that detachments, when sent out as feints, do not proceed so far from the army as to be cut off, or compelled to retire with great loss.

In the usual order of march the artillery should be formed in divisions corresponding to those of the troops, in order that each column may have a portion attached to it, and ready to act with it in the event of being obliged suddenly to come to action independently of the rest of the army. A few pieces of artillery generally accompany the advanced-guard in order to protect the deployment and commence the action; and a division composed of the heaviest pieces may move with the cavalry for its support. During the march, the place of the artillery is in rear of the column to which it belongs, that it may not impede the movement of the troops; that of the reserve artillery being behind the centre column, in order that it may readily move up to the position in which it is to be employed. If some point of attack has been previously decided on—if, for example, it is intended to commence an engagement by assailing a village or an intrenchment—a considerable division of the artillery must accompany the columns destined for that purpose; and if the army while making a flank-march is likely to be attacked on the road, some artillery proceeds at the head of each division of the troops. Should an attack in such circumstances take place, the troops must form as quickly as possible, and the artillery must be placed where it may serve to repel the assailants by its fire.

If an extensive movement is to be made in order to arrive at the position of the enemy, it is necessary to be careful that the latter may not, by short routes, attack the army on the march. This manœuvre was successfully performed by the Prussians at Liegnitz in 1760: the king, being surrounded by the Austrians and Russians, and in danger of being overwhelmed, on learning that the corps of General Loudon was moving to turn his left and fall on his rear, while other troops were to attack him in front, suddenly decamped, leaving troops and artillery to occupy the attention of Marshal Daun in front, and defeated Loudon on his march: by this action he opened a communication with Breslau, and caused the siege of Schweidnitz to be raised.

In all marches the breadth of a column must depend upon that of the road, and space should be afforded for the officers and orderlies to pass by the side of the troops without inconvenience: care should be taken when any change is made in the breadth of a column previously to entering a defile, that the formations be made without allowing the troops to fall into confusion.

To force a defile which is occupied by an enemy possessing artillery, and covered by epaulements, is an undertaking which is likely to be attended with some loss: but if it is necessary to attempt it, the troops which guard its entrance should be dispersed by a fire of artillery; and then the infantry of the army may enter the defile protected by light troops and artillery placed on the slopes or summits of the heights, in situations where their fire may act with effect against the enemy's position, or against the posts which he may occupy. These detachments must be followed by reserve troops, by whom they may be strengthened, or on whom they may retire if repelled. The enemy is thus, if possible, to be driven from every post by which the defile, with its parallel or transverse passes, if such there be, is flanked; when the main body of the army may dispose itself in the position which shall appear most favourable for maintaining possession of the ground while the enemy remains in the neighbourhood: strong detachments must also be placed in situations which may command every approach to the flanks of the defile.

In the event of having penetrated into the enemy's country, some strong posts should be secured, in order that they may serve to protect the succeeding operations. Fortified places are usually on rivers, or in situations from whence cross roads diverge into the country; and the possession of even one such place would be advantageous, as a depôt for artillery and stores, while the rivers or roads would facilitate the conveyance of supplies to the army.

On the other hand, in order to defend or cover a country, an army should be posted so that by short movements it may reach the enemy; and it must be understood that, in acting on the defensive, the corps of troops should not be stationed at great distances from each other, in the expectation of being able to defend every point which may be menaced by the enemy. This error was committed at the opening of the campaign in 1809, on the advance of the Austrians in great force towards the frontiers of France; when General Berthier so separated the divisions of the French army, that all of them might have been separately defeated, had the movements of the Archduke Charles been more rapid than they were.

When two armies are in the neighbourhood of each other, an engagement, either general or partial, may take place: the latter usually consists in an attack on one wing, or on some advanced part of the enemy's line, in order, by driving it back, to obtain a more advantageous position, or to secure some line of communication. A general action may become necessary when an invasion of a country is to be prevented, when a besieged fortress is to be relieved, when the position occupied is to be defended, or when that which is occupied by the enemy so far obstructs the communications as to deprive the army of the means of subsistence. A battle may also be hazarded if the position of the enemy be disadvantageous, if the divisions of his army are ill supported, or if his force is weakened, either from some part being badly covered, or from considerable detachments having been made.

An army drawn up for parade is usually disposed in two lines, with the infantry in the centre of each, and the cavalry on the wings; but this is far from being the case on service, since the nature of the ground will frequently render a contrary disposition necessary: in some parts of the field the troops may be in a single line, in other parts in two, or even in three lines.

The order of battle immediately previous to an engagement depends so much on the facility which the ground may afford for disposing and moving the troops, that it is scarcely possible to assign any rule for the formation; yet it is usual among military writers to class all the different dispositions of an army under two kinds, which are designated the *parallel* and the *oblique* order. The first comprehends all dispositions in which the troops of both armies may be engaged at once along the whole of their fronts: it was very generally employed by the Greeks and Romans, and during the middle ages: but it is now seldom adopted, since the weaker army is in danger of being outflanked; and should any part of it be driven back, the rest of the troops would either be turned and thus cut off, or be also compelled to retire. The battle would therefore be lost; and, being closely pursued, the defeated army incurs the risk of being entirely ruined. At the battle of Talavera, July, 1809, the two armies were drawn up in parallel order, and the attack was made by the French at the same time on the centre and on both wings of the allies.

The oblique order of battle may be said to have been employed by the ancients when it was intended to break the enemy's line: on such occasions the phalanx was drawn up in the form of a wedge, and it advanced with an angle in front against the centre of the line. At the battle of Arbela, the army of Alexander attacked only the right wing of the Persians; and at the battle of Cynoscephalæ, the consul Flaminius, ordering one of his wings to remain on the ground which it then occupied, advanced with the other against the army of Philip. (Polyb., ex. 3, lib. 17.) But this order of battle was first employed on sound military principles by Frederick III. of Prussia.

It does not always consist in drawing up an army in a straight line, which, if produced, would meet the line of the enemy; for this, on account of the inequalities and accidents of the ground, is seldom possible: nor are the two wings of an army always placed at unequal distances from those of the enemy, though this is frequently the case. The principle of the oblique order consists in such a disposition of the troops as may enable a portion of the army to engage at some one point in the enemy's line, while the rest, protected by the obstacles of the ground, is stationed so as to be able to support the troops engaged, or prevent the enemy at other points of his line from attacking those troops in flank; and a great commander will always manœuvre so that his army, even though inferior on the whole to that of the enemy, may be superior in strength at the point of attack.

The attack is generally directed against one of the enemy's wings in the hope of being able to turn it, that is, to get beyond its extremity, or in its rear, and thus to cut off its retreat or intercept its supplies; but if the wings are well protected by the ground, or by intrenchments, or by strong reserves being posted there, and if at the same time the centre has been weakened by troops having been drawn away, or by those which form it being widely disseminated, the attack may be advantageously made against that part of the line. At the battle of Corunna, January, 1808, the British and French armies were in oblique order, the right of the former being near the left of the latter; while the opposite extremities were, by the nature of the ground, kept at a considerable distance from each other. The French made a charge with two strong columns, one of which advanced towards the British centre, and the other attempted to turn its right: in order to take this last column in flank, a part of the British army was placed obliquely to the line; and its fire, together with that of the reserve, which was moved up to the support of the right wing, prevented the success of the manœuvre. At the battle of Eckmühl (1809), Napoleon with his right wing attacked and defeated the left of the Austrians: by this success he cut them off from Vienna, and compelled them to retire towards Bohemia. Again, at the battle of Borodino, in 1812, the French attacked the Russian army at its centre and on its right wing, and succeeded in gaining the heights in that part of the position, after having suffered immense loss in storming a redoubt which protected them, and which was gallantly defended by the *élite* of the Russian nfantry.

Whatever be the order of battle, a strong reserve of troops is necessary, in order that any part of the army may be succoured by it when weakened by losses, or when in danger of being overpowered by numbers. At the battle of Albuera, the timely bringing up of the reserve, when the first line was destroyed, was the means of the victory being gained; and at the battle near Bayonne, December, 1813, two British regiments having been improperly withdrawn from an important position, that position was in danger of being lost, when General Hill brought up the reserve and maintained the action. Strong reserves are particularly necessary when armies engage on a plain, as then the whole line may be forced into action, and in the event of being defeated, its ruin would be inevitable without the support of a numerous body of troops.

When cavalry commence an action, its charge should be preceded by a fire of horse-artillery placed on one of its wings. The fire of that artillery should at first be directed against some part of the enemy's line which is at a distance from the point to be attacked; and if the latter point should be weakened by troops being withdrawn from it to strengthen that point against which the fire is directed, the artillery and cavalry immediately move rapidly forward: the former, having discharged some rounds of grape-shot, retires, and the cavalry is left to execute its charge. Should the artillery become mixed with the combatants, it would be in danger of being taken by the enemy, whereas, being kept in reserve, it may after the charge either join in the pursuit or protect the retreat.

Infantry generally commences an attack by a fire of light troops; and these are accompanied by a part of the artillery, which joins in the firing, the rest remaining in reserve. If the skirmishers retire in order to allow the first line of the army to engage the enemy, the reserve artillery is brought up with that line, and it disposes itself by the side of that which had previously been in action, or it goes to one of the wings. Should the enemy's line become disordered, the horse-artillery gallops up to within range of grape-shot and completes the victory.

The stations of artillery in position should, if possible, be such that the fire of the guns may converge towards some battery of the enemy, in which case the fire of such battery against those guns is necessarily divergent. In general, when an army acts on the offensive, the lines of fire from batteries in position should form nearly right angles with the front of the position, in order that the attacking columns may have room to form in the intervals between those lines of fire; but if the enemy be the assailant, the lines of fire may form acute angles with the position, in order that he may be thereby annoyed when nearly in contact with the troops; the fire of the artillery being directed against the points where the enemy's troops are in masses, as against the heads and flanks of the columns of attack. The guns should not, however, be placed in position till they are wanted, in order that they may be as little as possible exposed to the fire of the enemy; and if any battery is subject to a heavy cannonade, another should be immediately placed in a situation where its fire may cross that of the first battery on the ground occupied by the enemy's guns. When placed on elevated ground, the guns in a battery should be able to defend all the slope of the height up to them; and when that is not possible without bringing them so near the brow as to be exposed to the view of the enemy, other guns should be placed where their fire may flank the ascending ground.

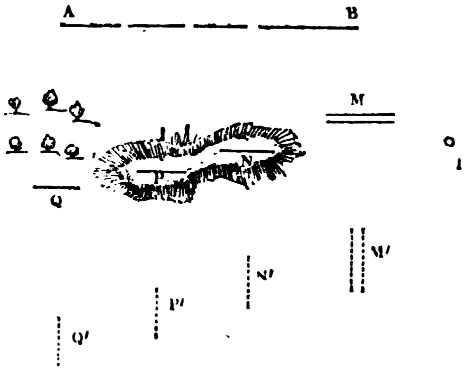
Artillery consisting of 9-pounder guns is found most convenient for the batteries which are placed with the troops: such guns are capable of serving to defend the position, and they may be employed to destroy walls, displace abatis, or ruin field intrenchments. Howitzers are also used in the field for the purpose of throwing shells into redoubts or villages, or among troops protected by hedges, hollow ways, &c., where the shot from gun-batteries could not take effect. To these must now be added rifled guns. [ORDNANCE, RIFLED.] Horse-artillery should be kept with the reserve, and be ready to advance wherever it may be required, either to support a part of the line which is likely to be forced, or to gain the flanks or rear of the enemy; and when it is required to get possession of a position before the enemy can arrive at it, the horse-artillery, on account of the rapidity of its motion, may be employed for the purpose.

The batteries by which an army is protected in its position constitute a sort of bastions, being usually placed a little in advance of the infantry of the line. If the army receives the attack of the enemy, the artillery commences the action by a cannonade while the enemy is at a distance; and if the army acts on the offensive, the artillery supports the columns of attack. It is usual, when guns are fired in position, to direct them so that the shot may strike the ground in front of the enemy's line, and afterwards, by rebounding, make a series of grazes among his troops. When the ground is hard and even, these ricochets are very destructive; but if soft, or much broken by inequalities, the shot plunges in the ground and does comparatively but little execution. It is doubtful if ricochet fire is practicable or likely to be efficacious with rifled ordnance.

The best proportions for the quantity of artillery in an army is one gun for every 500 men (infantry), and one gun of the horse-artillery for every 250 men (cavalry); but this will vary much with the country in which it is to be used, hilly country requiring much less artillery than level country.

Armies, whether on the offensive or defensive, are generally kept in columns till the proper moment for deploying has arrived; for by this disposition both parties are enabled to conceal their projects from each other till one of them has determined to commence the action, and each is in a condition to make such movements as may be necessary in order to give him an advantage over his opponent. The Spanish general, Cuesta, is blamed for having, at the battle of Medellin (1809), in which he was defeated, advanced towards the French army in one weak line three miles long, when, by keeping the troops in columns, he might have moved them between the enemy's divisions, and thus, by separating them from each other, have destroyed them in detail. If a position is such that the army occupying it is exposed at several points to be attacked, those points should be occupied by small bodies of troops, the bulk of the army being kept behind in columns ready to march to any point where their services may be required. Thus the enemy will be embarrassed from the impossibility of determining the force of the army at any one point, and his only chance of success will lie in the quickness of his movements. The circumstances which may determine a general to attack a position at any particular point are, the appearance of that point being weak on account of troops or artillery being withdrawn, from the ground being there more easy of access than elsewhere, or from its capabilities of affording cover to troops in their advance.

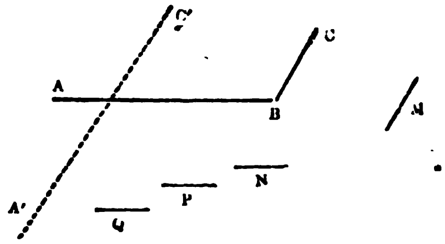
If an army, as A B, in position on level ground, is to be attacked on its left wing, B, the army acting against it is usually placed *en échelon*, as at M, N, P, Q, each division consisting of a battalion or a brigade; and this formation may be accomplished by moving up the different columns, as at M′, N′, P′, Q′, to the places which, when deployed, they are to occupy during the engagement. It would be advantageous, however, that the heads of the columns should remain till the moment of deployment in a line parallel to that of the enemy, in order to keep the latter as long as possible in suspense respecting the real point of attack. A favourable moment is then chosen for bringing the greatest mass, as M′, to the wing at B, which is supposed to be the weakest part of the line; but it should be observed that this intention will succeed only when the different columns can be moved to their stations with great rapidity, for if the enemy has time to perceive the manœuvre he will not fail to take measures to counteract it. The échelons must always be so near one another as to allow them to be mutually supported, yet not so near to the enemy as to be in danger of being forced into action. In order to explain the process of turning an enemy's position, let it be supposed that the left wing (B) of his line is in a plain, and not well protected by works, and, consequently, that it may be turned, while the right wing (A) is covered by woods. Strong columns are formed at M in order to perform the manœuvre of turning the flank B. The divisions at N and P constitute the centre, and may be supposed to be on elevated ground, so as to be refused to the enemy; while Q may consist of a small division extended along the skirts of the wood merely to keep the enemy in check.



Should the enemy reinforce his left, B, by drawing troops from his right, A, and should this circumstance become known after the troops M have set out on their march towards B, the infantry of the column M may then change their route and proceed towards N and P, concealing their strength as much as possible by passing through woods and hollow ways, if such there be, while the cavalry, supported by some infantry in a village, as at I, move towards M as before, in order to deceive the enemy. The central columns P and N then move towards their left, and unite with the trooops Q to attack the wing A. Thus the disposition of the army is completely changed: and if the change is effected with rapidity, the enemy might not have time to reinforce the wing A before it would be turned. If the troops in the wing B were to advance to attack the central columns at P and N, and these were to retire, those troops would be unable to produce any effect, as it would be necessary to recall them in a short time on account of the danger then threatening the right wing.

This is nearly what took place at the battle of Leuthen (1757), when the king of Prussia advancing against the Austrian army, made demonstrations as if he would attack their right wing. Marshal Daun, though for a time he suspected the feint, was at length deceived, and sent all his reserves to strengthen that wing: the king observing this, proceeded immediately to execute an oblique attack; for which purpose his columns moved rapidly to the right and deployed on the left wing of the Austrians; this wing gave way, and the right wing wheeling up to attack the Prussians' left, the two armies were brought into parallel positions. These movements produced in the Austrian line disorder, and openings by which the Prussian cavalry penetrated and took possession of the village of Leuthen: the Austrians rallied twice afterwards, but they were finally obliged to retreat. At the battle of Albuera (1811) the French general at first moved his columns as if he intended to attack the left of the allies, but soon causing them to change the direction of their march, he rapidly placed nearly two-thirds of his army in order of battle perpendicular to the right of the British line. By this movement the allies were obliged to change their front, and, as this was done under a heavy fire, the enemy was upon them before they had time to complete the new formation.

When an army, in the position A B, is attacked on one wing, as B, by the corps M, and is in danger of being turned, it may endeavour to prevent the success of the manœuvre by throwing back that wing in a direction B C, parallel to that of the attacking corps, M: this is called forming the army *en potence;* the angle B is, however, weak, for the troops in B C by falling back may become crowded and disordered; A B may become exposed to a raking fire from M, and B C to a like fire from troops at N. It is evident, however, that M cannot now turn the flank B C without making a circuitous movement, by which it may become separated from the rest of its line: and if the army A B is strong enough, it may form a line parallel to the direction of C B. By such a movement the parallel order would be restored, and the wing A might even be made to turn the left, Q, of its opponent: this should of course be attempted, as the return to a parallel order of battle leads to no useful result. In order to effect it, the division B C should retire gradually, while the brigades in A B wheel back, in order to keep in connection with it; at the same time the brigades at A wheel to their front so as to form the new line A′C′, in a direction oblique to that of Q, P, N.



An attack on an enemy's line is often made by a strong division drawn up in one column for the purpose of forcing its way through the line at some point where it appears to be weak, and thus compelling the different corps to retire that they may not be separately overwhelmed. This is the mode of attack which was practised with so much success by Napoleon against the Continental armies, but which failed when attempted against the British troops, both in Spain and at Waterloo.

It is adopted when an attack is to be made on an enemy behind retrenchments, in which case the troops move as much as possible towards the salient angles of the work in order to avoid the direct fire; it is also necessary when the ground only permits the troops to advance on a narrow front, as in defiling through a ravine; in fact, if an enemy's position have obstructions in its front, it must necessarily be attacked in columns if at all. The columns should be connected with each other by bodies of light troops, and the attack should be made with a view of separating a wing of the enemy from his main body.

The attack in column possesses some advantages over one made by troops deployed in line while the men remain steady in the column; for the enemy is intimidated by the sight of a vast body coming against him, while the assailants feel confidence from their union. A rapid succession of efforts directed against troops in a slender line will also, in general, succeed in breaking their order; but there are several circumstances which more than counterbalance these advantages: during the advance over uneven ground the men lose their ranks and fall into confusion; the flanking fire of the enemy's artillery makes great havoc among the crowded masses, and the columns can only oppose this fire by an irregular fire from its sides; disorder then ensues, the commands of the officers are no longer regarded, and an attempt to deploy for the purpose of making an attack in line only completes the disorganisation. An attack in column can indeed, scarcely succeed unless it were preceded by a heavy fire of artillery: this will put the enemy's line in disorder; and in the event of forcing it, the column may then be deployed in order to secure its advantages.

If a line, nearly equal in strength to that of the opponent, on being attacked in column, were to stand firmly, it is probable that the attack would fail; and even if the line were penetrated, the troops, by forming themselves in hollow squares, disposed chequer-wise, so that their fires may cross on the ground in their front, have invariably been found capable of resisting the efforts of the assailants. This last manœuvre was recommended by General Jomini, and was for the first time employed at the battle of Aspern, in 1809. In that action Napoleon, perceiving the Austrian line to be weakened in the centre, ordered it to be attacked by the whole corps of Marshal Lannes, which for this purpose was drawn up in one great column. The column, preceded by artillery, advanced rapidly, and succeeded in penetrating the line. The troops in that part gave ground, but forming themselves in squares, they resisted all the efforts of the French cavalry to disperse them, while the wings of the army closing upon the flanks of the column, poured into it a destructive fire of artillery, which at length forced it to retire in confusion between the two fortified villages which supported its wings. The attack of the French at the battle of Wagram had, however, complete success: the Austrians, being doubtful of the precise spot at which Napoleon would cross the Danube, had very widely dispersed their troops; the centre of their line was particularly weak, and against this part the French emperor determined to direct a dense column. This was composed of the reserve of the army, and the charge was preceded by a heavy cannonade, which still further dispersed the Austrian troops. The army, being thus broken, was compelled to retreat. At the battle of Talavera (1809), the French in strong columns attacked, at the same time, the centre and both wings of the British line. The latter was drawn up three deep, and its fire of musketry and artillery, directed against the heads and flanks of the columns, aided by charges of cavalry, drove the enemy back with great slaughter. An indiscreet pursuit made by the Guards was the cause of much disorder in the centre; and the enemy returning to the charge, that part of the line was completely broken; but fresh troops being ordered up to the spot, their fire kept the enemy in check till the disordered troops rallied, and the artillery continuing to play on the flanks of the enemy's columns, the latter at length gave way.

The success of an action is often promoted by sending out a detachment with directions to fall on the flanks or rear of the enemy during the engagement. The sudden appearance of a body of troops in such a situation cannot fail to produce embarrassment in the army which is attacked, and to diminish the energy of its operations towards the front. On the other hand, there is some danger in sending out large detachments from an army, as it is seldom possible to afford them due support; and therefore they may be cut off by the enemy. The distance which the detachment has to march, together with the state of the roads on which it must move, should be ascertained with precision, in order that it may be at the appointed post at a seasonable moment; and such determinations are very uncertain, particularly if the corps has to make a great circuit. It almost always happens that the detachment arrives too late for the accomplishment of the object; and this was the case with a detachment sent by the king of Prussia during the action at Torgau (1760), with a view of turning the left of the Austrians, and cutting off their retreat.

Detachments are however constantly sent out to protect the parties reconnoitring a country, to guard a convoy, or to support a foraging party. In these cases its object is less to fight than to cover a retreat; therefore the troops advance with circumspection, and retire when the enemy appears in superior force. During the war in Spain (1813), Colonel (Sir Frederick) Adam having been detached to occupy a post at Ordal, ten miles in advance of the army under Lord William Bentinck, in Catalonia, was suddenly attacked by the French army, and his troops dispersed. This misfortune is ascribed to neglect in not having placed outposts, by which warning might be obtained of the enemy's approach.

An army which gains an advantage over its adversary is always more or less deranged by the action, and it is necessary that it should endeavour to recover its order preparatory to receiving the second line of the enemy, should the latter advance to renew the combat. On the enemy retiring, the first line of the victorious army advances, and then the second line follows it in order to support it, sending, if necessary, battalions or squadrons to replace such as have been most disordered during the action. In the event of the second line, or reserve, of the enemy being defeated, since then there is no apprehension that the action will be continued, companies of troops may be detached in pursuit of the retreating army; but every precaution should be taken to keep them within the support of the main body, and particularly to prevent the troops from dispersing for the purpose of plundering the country. The advance of the whole army in pursuit should continue so long only as it can be conducted with order, and in masses strong enough to oppose the enemy if his troops should rally in a good position. If disorder should take place among the pursuers, the latter should be made to fall back on the reserves: the pursuit of a retreating army can, indeed, be seldom continued beyond the first elevated ground at which the latter may arrive; since, however little discipline it may preserve, it may there rally and return to the order of battle. The consequences of the actions at Jena and Waterloo are exceptions to this rule, because the vanquished armies were at those places too completely disorganised to allow them to make any attempt to rally.

When the success of an action begins to be doubtful, and it is apprehended that the army must retreat, some of the heaviest artillery should be drawn off to a good position on heights, or behind streams or hollow ways, while the lighter artillery remains engaged. The first line of the defeated troops is then made to pass through the intervals of the second, or of the reserve, while the latter continues the action. The first line should remain in order of battle in rear of the second, till the latter is enabled to retire; and this alternate retreat of the lines should be continued till the army can be thrown into columns of march, when the retreat may be protected by detachments of light troops. In general the retreat should be made in one body, as thus it can more easily protect itself against the enemy in pursuit. If, however, the centre is broken, the army may be obliged to retire by different and even by diverging routes; and, provided there are in the rear strong posts by which it may be protected, the risk of being cut off during such a retreat is small.

When there are narrow defiles in rear of the field of battle, the retreat through them becomes extremely dangerous, for the army may be overtaken before it can get through; and if they are already occupied by the enemy's detachments, the retiring army may be annihilated or compelled to surrender. It has been observed that the situation of the British army at Waterloo would have been very critical if it had been compelled to retreat; this criticism, however, is hardly just. The British army had good roads to retire by, and the open forest in rear would have been an admirable position for defending the rear of the retreating columns. In order to pass a defile in safety, it ought to be previously occupied by troops: artillery and a reserve corps should also be stationed so as to defend the approaches on the advance of the enemy towards them.

If, when not in action, an army is to retreat from a position which it occupies, the movement is usually concealed from the knowledge of the enemy, and, for this purpose, it frequently takes place at night. On such occasions the outposts remain at their stations as long as possible; and fires are left burning on the ground, as if the army were still in the position: after it is dark the main body moves off, and the rest of the troops follow by degrees.

The approach of winter, and the necessity of taking repose after the fatigues of a campaign, render it necessary for armies, whether on the defensive or otherwise, to take up positions where they may remain during the season of inaction. These positions, called winter-quarters, should be chosen by the commander of the army on the offensive, so that he may be able to preserve the ground which he has gained; and by him who is on the defensive, so as to be secure against the attacks of the enemy. The principles by which a choice of quarters is determined are the same as those which regulate the occupation of ground for a field of battle. The quarters should be covered in front and on the flanks by rivers or other natural impediments to the approach of an enemy, or by forts constructed for defence.

A great extent of ground in front is therefore a disadvantage, as some part may be ill-guarded, and liable to be surprised, and the troops will be too much disseminated. If it is traversed by great roads perpendicular to its front, it is also disadvantageous, as the enemy may then easily march into the quarters.

Several battalions of infantry and squadrons of cavalry are quartered in villages along the front of the position; the whole or a division of a company or of a squadron at each place: these posts may be strengthened by redoubts, palisades, or abatis; retrenchments also should be executed, to defend roads by which the enemy may approach, and bridges over the streams should be destroyed. The troops in each of these stations furnish the men necessary to constitute the advanced posts of the chain. A stronger force should occupy villages and towns within the first chain, and from these are sent such bodies of troops as may be requisite to support those in their front. The great body of the troops ought to be near a central point of the position, in order that succours sent from that body may easily reach any part that may be threatened.

When an army is in quarters, there are established alarm-posts, at which the troops should be appointed to assemble. These are frequently in the vicinity of a fortress, that the corps may be protected by the latter till all have assembled; but they should be in commanding situations, that, in the event of the enemy attempting a surprise, his movements may be easily seen. Each division, or corps of the army, should have its own alarm-posts, and there should be, besides, the general place of rendezvous for the whole army: the latter place should be so situated that all the divisions may be drawn up there before the enemy could arrive at it, and it should be protected by a fortress which may contain the provisions for the support of the troops.

A system of signals, for day or night, is determined on, by which intelligence may be conveyed to all the different posts, of the approach of the enemy. Should an alarm be given by any outpost of the chain, the bodies of troops which are appointed to support that post take arms, attach the horses to the artillery, and prepare to march immediately to the point of danger; but the judgment of the commander, and the information which he may receive from spies or deserters, must enable him to form an opinion whether a demonstration made by the enemy is true or false.

(Bulow, *Esprit du Système de Guerre Moderne*, 1801; Guibert, *Œuvres Militaires*, 1803; Jomini, *Précis de l'Art de la Guerre ou Nouveau Tableau Analytique;* Rogniat, *Considérations sur l'Art de la Guerre*, 1817; Lallemand, *Traité des Opérations Secondaires de la Guerre*, 1825; Yates, *Elementary Treatises on Tactics and Strategy*.)

WARD, WARDEN, that is, "guard" and "guardian." Ward is the name used in the counties of Durham, Westmoreland, and Cumberland, instead of the hundred of the midland counties or the wapentake of Yorkshire, to denote a subdivision of those shires. The neighbourhood of those border counties to the Scots rendered it essential that the military preparation of the inhabitants should be constant; and hence the subdivision of the county took the warlike appellation of ward, rather than the more peaceful one of hundred. The great officers whose duty it was to defend the northern borders from the Scots, and the north-western from the Welsh, were called lord-wardens of the marches [MARCHES]; and we still have the lord-warden of the Cinque Ports, the lord-warden of the Stannaries. To descend to a lower class of functionaries, a castle or tower was heretofore often called a ward; and it served as a place not only of defence, but also for the safe keeping of malefactors: hence the keepers of some jails are called wardens; for example, the keeper of the Fleet prison, until it was abolished, was called warden.

Forests were divided into wards. By the Municipal Reform Act (5 & 6 Will. IV., c. 76,) cities and boroughs are divided into wards, each of which has the right of electing an alderman and a certain number of council-men. [MUNICIPAL CORPORATIONS.]

WARDS, COURT OF. The Court of Wards and Liveries was established by the statute 32 Henry VIII., c. 46, to superintend the inquests which were held after the death of any of the king's tenants by knight's service, for the purpose of ascertaining what lands the tenant died seised of, who was his heir, whether the heir was an infant; and thus what rights accrued to the king in the shape of relief, primer seisin, wardship, or marriage.

By the famous statute passed in the first Parliament of Charles II. (12 Charles II., c. 24), the Court of Wards was abolished, together with the feudal rights out of which that court arose. The preamble of the statute states that it had been intermitted since Feb. 24, 1645. [GUARDIAN.]

WAREHOUSING SYSTEM is a customs' regulation, by which articles of import may be lodged in public warehouses at a moderate rent, not being chargeable with duty until they are taken out for home consumption, and being exempt from duty if re-exported. It affords valuable facilities to trade, is beneficial to the consumer, and ultimately to the public revenue. Where no such system exists, the merchant must either pay the duty on every article immediately it is landed, or must enter into a bond with sureties for payment at a future time. If he pays at once, he is obliged to advance a large capital, on which interest must be charged to the consumer until the goods be sold; or he must effect an immediate sale, perhaps at an inadequate profit, or even at a loss, in order to raise the funds necessary to pay the duty. If he wishes to defer the payment until the market shall offer an advantageous sale, he may find it difficult to induce persons to become his sureties, and, when he has succeeded, he may involve them in ruin. The natural result of these difficulties is, that none but wealthy capitalists can import articles on which heavy duties are charged, and a monopoly is thus established, to the great injury of the consumer. The immediate payment of customs' duties also obstructs the carrying trade of a country, by making the re-exportation of articles more troublesome as well as expensive.

The first British statesman who proposed a remedy for these evils was Sir Robert Walpole, in his celebrated Excise scheme, in 1733. His object was to unite the Excise laws with those of the customs as regarded wines and tobacco, and to charge a small duty immediately on importation, and the remainder on being removed from the Excise warehouses for home consumption. Speaking of tobacco, he thus explained his proposal:—"If the merchant's market be for exportation, he may apply to his warehouse-keeper, and take out as much for that purpose as he has occasion for, which, when weighed at the custom-house, shall be discharged of the three farthings per pound with which it was charged upon importation; so that the merchant may then export it without any further trouble. But if his market be for home consumption, that he shall then pay the three farthings charged upon it at the custom-house upon importation; and that then, upon calling his warehouse-keeper, he may deliver it to the buyer, on paying an inland duty of 4*d*. per pound to the proper officer appointed to receive the same." Walpole clearly foresaw the advantages of his scheme to the carrying trade. "I am certain," he said, "that it will be of great benefit to the revenue, and will tend to make London a free port, and, by consequence, the market of the world." This wise plan, unfortunately for English commerce, was not permitted to be carried into effect.

The advantages of the warehousing system were most forcibly pointed out by Dean Tucker in 1748, in his 'Essay on the Advantages and Disadvantages which respectively attend Great Britain and France with respect to trade,' and afterwards by Adam Smith, in his 'Wealth of Nations;' but it was not established before 1803 (43 Geo. III., c. 132). The acts by which warehousing is now regulated are the 3 and 4 Will. IV., c. 57; 4 and 5 Will. IV., c. 89; and 6 and 7 Will. IV., c. 60.

The main objection to Sir Robert Walpole's scheme was that the warehousing was compulsory, but, under the existing law, it is at the option of the importer. Amongst other privileges enjoyed by the merchant, he may remove any merchandise from one port to another, either by sea or inland carriage, to be warehoused again. A committee of the House of Commons reported, in 1840, "that the privilege of having bonding warehouses may be conceded to inland towns, under due restrictions and regulations, with advantage to trade and safety to the revenue. An Act (7 & 8 Vict., c. 31) conferred this privilege upon Manchester. Since then the power of appointing warehousing ports has been conferred on the Treasury by the Customs Consolidation Act of 1833; and a similar power as to inland towns by the 23 & 24 Vict., c. 36.

The advantages of warehousing have been understood in various foreign countries as well as in England. So long since as 1664, M. Turgot established it in France; but it was discontinued in 1668, except for merchandise imported from the East and West Indies and Guinea, or exported thereto. In 1805 the system was re-established in a more extensive manner, but was confined to certain sea-ports, until 1832, when it was extended to several of the principal cities in the interior. Warehousing both at the ports and at certain inland towns is permitted in Holland. In Belgium, Denmark, and most other commercial countries the system has also been adopted.

WARMING AND VENTILATION. References having been made from Smoke, Stove, and Ventilation to the present article, it will be desirable here to glance rapidly at the principal modes employed for warming and ventilating buildings generally.

Open fire-places.—A "cheerful English fire" is associated with so many ideas of comfort and social enjoyment, that we are apt to forget how dearly we pay for it. Dr. Franklin and Count Rumford did something to call attention to the subject, but Dr. Arnott has done more. In order to understand this matter, it will be necessary to bear in mind that, while some fire-places or stoves give out heat by *conduction* chiefly, others do so mainly by *radiation*. Open fire-places are of the latter kind, and a serious loss of heating-power results from the arrangement. The burning coals radiate heat into the room, and another portion of heat is reflected from the metallic portions of the grate; but the heated air, which ought to contribute to the desired effect, is mainly allowed to escape up the chimney with the smoke and other results of combustion.

Dr. Arnott enumerates about a dozen evils which are more or less inseparable from the familiar open fires of our apartments. Among these are: *Waste of fuel.*—There is, first, the heat which escapes with the smoke; then the current of warmed air from the room, which ascends the chimney; and, lastly, the valuable fuel contained in the smoke itself. From all these causes Dr. Arnott estimates a loss of seven-eighths of the whole heating-power, while Rumford estimated it as high as fourteen-fifteenths—each basing his conclusions on the kind of open fire-place chiefly in use in his own day. *Unequal heating.*—In a cold wintry day, when seated near a large fire, we may frequently hear persons complain of being scorched on one side and frozen on the other. This arises from the circumstance that, as most of the heat received from an open fire is radiated from the burning fuel, instead of being conducted by the air, this heat, diminishing in intensity as the square of the distance increases, is very unequal, being too great at a small distance, and too weak at a greater; while the draught, or current of cold air which feeds the fire with oxygen, acts like a chilling blast against the side of each person or object which is turned away from the fire. *Strata of air unequally heated.*—Besides the inequality just alluded to, there is another, arising from this circumstance—that the entering current, being colder and specifically heavier than the air previously in the room, occupies the lowest stratum, and subjects the feet to a cold bath, which is frequently attended with bad consequences. Other objections are—the *smoke and dust* arising from the use of open fires; the *loss of time* attendant on the care which they demand; the *danger to property and to person* which accrues from them; the *necessity* (until lately supposed to be indispensable) *of employing climbing boys;* and many others.

Many contrivances have from time to time been brought forward to obviate one or other of these inconveniences. Count Rumford suggested the register-stove, the peculiarity of which consists in narrowing the entrance or throat of the chimney by a plate which can be moved to vary the size of the aperture; by this means, particularly if the opening be near the fire, the very hot air directly from the fire enters before it can mix with much colder air from the room, and thus the draught is increased so as to lessen the chance of smoking. But the very circumstance which constitutes the excellence of this stove, namely, the rapid ascent of heated air up the chimney, illustrates the waste of the method generally by showing how much of the heating agent is lost. The almost interminable variety of open fire-places, both in the form of the grate itself and in that of the opening in which it is placed, have been introduced either for an ornamental purpose or for the prevention of smoking; the other evils enumerated are almost inseparable from the system.

Dr. Arnott, in 1855, published a volume "On the Smokeless Fire-place, Chimney-valves, and other means, old and new, of obtaining healthful Warmth and Ventilation." His chief object was to describe a kind of open stove which he had invented, as the result of combining many principles long known, but only in part acted on. In this, as in other cases, he generously threw all patent privileges aside, and sought how best he might serve the public generally. The chief faults of open fire-places being the production of smoke, waste of fuel, unequal heating, and troublesome management, he devised a plan for lessening, if not preventing, all these evils. One day's charge of fuel is supplied at once, in a box beneath the grate. The coal is borne upwards, when wanted, by a moveable false bottom in the box, which is raised easily by the poker as a lever, with notches and ratchets to retain the false bottom at any height. The box is from 8 to 18 inches deep, and contains from 20lbs. to 30lbs. of fuel. In warm weather, the fire is kept dull by not raising the bottom so high or so often as in cold weather. To light the fire, paper and wood are laid on the coal; and on this three or four inches of cinder or partially coked coal. The wood soon kindles the cinder, and the pitchy vapour from the coal rises through the wood-flame and cinder-flame, ignites, and adds to the heat, without producing smoke. It is important that no air should pass up through the coal-box; to insure this, the false bottom moves up tightly. The coal only burns at the top, but it keeps a-light with great tenacity. Even if no fuel were left in the grate, the coal in the box would burn gently downwards, and endure through a whole night. The grate is accompanied by an improved form of chimney-valve, &c. Any kind of coal, culm, or coke will do. A room may be kept warm all night, by leaving the valve and throat of the chimney only a little open, and thereby drawing away only a little of the warmed air. Dr. Arnott, having tried his new open smokeless fire-place in many ways, has found that it saves one-third of the fuel, cures a smoky or ill-drawing chimney, ventilates the room through the valve, diffuses the heat about the room, requires no tending for twelve hours together, renders chimney-sweeping unnecessary, and calls for very little personal attendance. We may add that Dr. Arnott combats an opinion, now very prevalent, that a modern *low* grate warms the floor of a room better than one of greater height. In the usual position of a hearth-rug, more heat comes down upon it if the grate be moderately high. If the grate be low, hardly any heat *strikes* it; it merely passes horizontally *over* it, while cold air rushes along the floor in the opposite direction, on its way to feed the fire.

Close Stoves.—The common Dutch stove is one of the simplest examples of a close stove. It generally consists of a cylindrical case of sheet iron, within and near the bottom of which is a grating for containing the fuel. There is an ash-pit beneath the grating, and three openings to the interior—one to the ash-pit, one for introducing the fuel above, and one leading to a flue or chimney. When the fuel-door is closed and the ash-door open, there is then one aperture by which cold air can enter to feed the combustion, and another by which the smoke can escape. In this form of stove the heated iron case warms the air of the room by *conduction* rather than *radiation*, and all this air becomes much more nearly equalised in temperature than by a common fire. There is also great economy of fuel, and an absence of smoke and dust. On the other hand, inconvenience arises from the highly heated iron, the temperature of which is so great as to decompose many of the heterogeneous particles always floating in the air. The air acquires a burnt and sulphureous odour; it exercises a dry and shrivelling effect on objects in the room; and it often gives headache and giddiness to those who are exposed to it. In Germany the stoves are made on this principle, but are often more ornamental in their character.

The Russians contrive their close stoves on a different principle. Earthenware and brickwork are largely used, instead of metal, as a means of making the heat less intense near the stove, and of keeping up a reservoir of heat after the fire is extinguished. The stove is built in a massive style, and consists of a series of chambers, of which the lowest serves as the fire-place, and the upper ones as flues; and being composed almost entirely of brick and porcelain, the outer surface remains at a moderate temperature for a very long period.

Within the last thirty years many forms of stove have been devised, with the view of obviating some of the objections urged against those used on the Continent. Where, as in a common German or Dutch stove, the burning fuel comes in contact with the metal of which the stove is formed, this metal becomes so highly heated as to produce upon the surrounding air the deleterious effects before alluded to. Dr. Arnott has the merit of having drawn attention in a particular manner to this subject. The problem which Dr. Arnott sought to solve was, to obtain a considerable extent of surface heated not much above 200°, as a means of warming apartments. He first caused a kind of water-stove or tank to be constructed, having a fire-box in its centre; and by certain arrangements for the admission of air and the emission of smoke, he kept the water always nearly at the boiling temperature. This apparatus being however both expensive and difficult to manage, he dispensed with the water, and surrounded the fire merely with a body of air. In the new form of stove, the fuel is put into a small fire-box, enclosed within a larger case of sheet-iron; the only openings in the outer case being a door at which the fuel is introduced, an air-hole beneath the grate, and a chimney for the exit of smoke, which chimney, being merely a metallic tube three or four inches in diameter, can be easily arranged in position. The interior of the outer case is nearly divided into two parts by a partition so adjusted as to cause a continued circulation of the heated air within, and hence an equable heating of the outer case. The air-vent leading to the fire is provided with a valve, by which the admission of air is rendered more or less abundant according as the fire within is less or more intense. It was one point in Dr. Arnott's system to make the stove a "self-regulating" one, by providing apparatus whereby the valve would open and shut at the proper times to maintain any required temperature; and he suggests six or eight different modes of arrangement, from which the maker of the stove may select one. Dr. Arnott states:—"During the winter, 1836-7, which was very long and severe, my library was warmed by the thermometer-stove alone. The fire was never extinguished, except for experiment, or to allow the removal of pieces of stone which had been in the coal; and this might have been prevented by making the grate with a moveable or shifting bar. The temperature was uniformly from 60° to 63°. I might have made it as much lower or higher as I liked. The quantity of coal used (Welsh stone-coal) was, for several of the colder months, six pounds a day; less than a pennyworth, or at the rate of half a ton in the six winter months." This kind of stove possesses many advantages; but it is not free from defects. It is liable to the objection already stated with regard to the unpleasant feeling consequent on the use of all stoves of the kind, and indeed with it more than others; for owing to the very slight expenditure of fuel, there is little or no change in the atmosphere.

Numerous varieties of the close stove, bearing more or less on the above construction, have been brought forward since the publication of Dr. Arnott's first book on this subject in 1838. Each professes to possess some peculiar merit; but all present these features in common: that the air-hole, by which the combustion is fed, is very small, and capable of adjustment; that there is a body of air to be warmed, external to the grate or fire-box itself, but confined within an outer case; that the consumption of fuel is much smaller than in any variety of open fire-places; and that the flue for carrying off the smoke and gases is small in diameter, and capable of being carried in any direction. In one variety, called the Vesta stove, there is a very ingenious arrangement whereby the ashes can be raked from the grate into an ash-receiver, and new fuel thrown into the grate, without any dust rising into the room, or any air entering the stove except through the customary air-vent. In the different forms of kitchen-ranges the open fire-place is combined with what may be deemed a close stove; for the oven and hot-closet are representatives of the heated space within the outer case of a close stove. The stoves often employed in shops, halls, &c., are adjusted not so much for the economising of fuel as for the consumption of their own smoke.

Gas-Stoves.—In addition to the use of gas for lighting, described in its proper place, gas is now extensively employed for heating, by means of stoves of various kinds. The stoves are mostly cylindrical in form, with openings at the top and bottom. At the lower end, a few inches above the floor, is a ring-burner pierced with numerous minute jet-holes. The top has frequently a sliding valve or damper to regulate the heat. The details vary greatly in different kinds. Edwards's gas-stove has bulbous-shaped burners of fire-resisting clay, pierced with numerous small holes. Air enters through a lower row of holes and mixes with the gas. The bulb becomes gradually covered with a thin yellow flame. Several such bulbs are combined in various ways, and arranged to form cooking and heating stoves. One form of this stove, the so-called *Atmopyre*, consists mainly of small cylinders of pipe-clay. Each cylinder is from two to four inches long, and perforated with holes $\frac{1}{50}$th of an inch in diameter. One end of the cylinder is fixed upon a gas-burner; the gas, being turned on, mixes with the atmospheric air in the cylinder; the little jets which penetrate the minute holes are ignited, the cylinder becomes red-hot, and presents the appearance of a solid red flame. By placing many such cylinders within another of larger size a very intense heat may be produced, applicable to manufacturing purposes.

Whatever form a gas-stove may present, its assumed advantages are: a comparative freedom from dust and dirt; a saving of time and labour; facility for adjusting the temperature of a room; and economy in cost and maintenance. The disadvantages are alleged to be: a diffusion of aqueous vapour, nitrogen, and carbonic acid gas; these ought to be carried off by a chimney or flue, which however is seldom provided for gas-stoves. Moreover, all the bad gases are given off near the floor (in gas-stoves, though not in gas-lights), so as to mix with the whole of the air in the room; and any defect in the burning of any one of the numerous small jets leads to the production of an offensive odour. To lessen these evils, it has been recommended that the stove should have two or three concentric cylinders; that the heated air should be allowed to circulate between them; that there should be no opening at the top; that a flue of two inches diameter should be placed at about mid-height, to carry off vapour, dust, and deleterious gases; that there should be an increased amount of metallic and reflecting surfaces to receive the heat; that only the *radiative*, not the *ascensive*, heat should be allowed to combine with the air of the room; that the size of the stove ought to bear some well-ascertained proportion to the size of the room; that care should be taken not to overheat the stove, for fear of producing an empyreumatic odour; and that the gas-jets should never exceed three-quarters of an inch in height. If the flue be long enough to allow the stove to stand near the middle of the room, nearly all the heat will be rendered practically available. In a well-arranged gas-stove seven-eighths of all the heat may be economised. A more equable heat can be maintained by such a stove than by any mode of using coal or coke, on account of the jet-holes remaining constantly of the same size. So far as regards safety, the flue of a gas-stove is not so likely to be highly heated as that of other stoves. Whether such a flue could be made conformable to the decorations or furniture of a room, instead of being an eyesore, is a question worthy the attention of architects and upholsterers. In relation to economical use, it has been calculated that a gas-stove will boil one gallon of water by the expenditure of gas to the value of one farthing; while a pennyworth of gas will bake three quartern loaves or six pounds of meat. On this subject, the application of gas to cooking, see COOKING APPARATUS.

Warming by Heated Air.—In all the arrangements yet described, the stove or fire-place is in the room which is to be warmed, and its heating effects are calculated with respect to that room alone. A notable advance, carried to a great extent in the present day, is to have the fire in an outer or lower apartment, and to carry the heated air from thence in a pipe to the apartment to be heated. The Chinese have been beforehand with us in this matter. In the better class of Chinese houses there are hollow flues extending beneath the floors, and connected with a fire-place constructed either against the exterior wall of the apartment to be heated, or else in an inferior room adjoining. The flues are perforated with numerous holes, through which they give out the heated air and smoke to the whole of the under side of the flooring. This flooring consists of flat tiles or flag-stones nicely imbedded in cement, so as to prevent the escape of the smoke or heated air from the flues beneath into the room. After circulating beneath the tiled floor, the smoke escapes by a chimney into the open air. In this arrangement it is obvious that the apartment is warmed by the conduction of caloric from the warm tiled floor to the air of the room; and as this conduction proceeds slowly, the tiles retain heat enough to warm the room many hours after the fire has been extinguished.

Before the improved methods of warming factories came into use, Mr. Strutt, of Derby, devised a form of stove which, under various modifications, was called the "cockle stove," the "Derby stove," and the "Belper stove," for warming his cotton-factories. In these stoves the fire was contained in an iron receptacle, shaped sometimes cylindrically, sometimes rectangularly; and at a certain distance from it, encompassing it on every side, was a brick casing or envelope, so that a body of air existed between it and the fire-box. The fire-box had three openings to the exterior, one to introduce the fuel, one for an ash-pit and air-vent, and one for a chimney; the exterior envelope had two openings, wholly distinct from the others, one to carry off heated air to the various rooms of the factory, and another to admit a renewed supply of fresh air. Dr. Fyfe describes an arrangement adopted in a church, which may perhaps be taken as a fair example of a numerous class of instances. The body of the church is warmed by two stoves about four feet high, made of cast-metal, and shaped nearly like a bell. A square ash-pit, about a foot high, rests on four balls, and supports a fire-box or furnace. Concentric with this fire-place is an outer case; the space between the two containing the air which is to be warmed. The usual adjustments are provided for the introduction of fuel and of air to feed it, for the exit of smoke, for the entrance of fresh air to the air-chamber, and for the exit of the heated air to perform its wonted office. The air-tubes, communicating with the air-chamber of the stove, are conveyed along the lower edge of the gallery of the church; and small branch pipes opening from them at regular intervals give out a stream of hot air which mingles with the cold air of the building. The fires are lighted early on the Sunday morning. From this time till the congregation assembles the fires are constantly supplied with fuel, and a supply of heat is thus kept up sufficient to warm the whole interior of the church during the time of divine service. A stove such as this is likely to give a tainted and offensive character to the air, like the common German stoves, unless a rapid current be kept up. Hence a change has been occasionally introduced, by having the outer casing made of brickwork, instead of metal, and by making its dimensions much larger, an arrangement which heats the outer case less intensely, and provides a larger body of air heated to a lower temperature.

Very numerous varieties of the hot-air apparatus have been brought into use; but the principle on which they all act can readily be understood. When the nave and dome of St. Paul's cathedral were recently fitted up for Sunday evening services during the winter, six stoves, constructed on a plan devised by Mr. Goldsworthy Gurney, were placed in the crypt. Gratings admitted the heated air from these stoves into the body of the cathedral. The vitiated air escaped by openings at the top of the dome. Each stove was a cylinder, with radiating wings all round. It stood in a vessel of water. The hotter the stove, the more the water evaporated, so as to keep the air in a proper hygrometric state. The steam generated from this water also carried off the heat from the iron quickly, and thus aided in warming the building.

Warming by Steam.—The employment of steam-boilers in large establishments where steam-engines are worked, is one of the circumstances which have led to the very extensive adoption of the method of warming by steam. A marked difference is observable in the principle of this method, as compared with that of hot-air warming. The heated agent, that is, the steam, is not permitted to mingle with the air of the room which is to be warmed, but acts through the medium of the metallic tube which confines it, and which it raises to a temperature sufficient to warm the room, without imparting a burnt quality to the air.

The general arrangements of a steam-heating apparatus, as suggested by Mr. Scott Russell, are somewhat as follows:—At a convenient part of the building, and as low as possible, there is to be placed a close steam-boiler of the ordinary construction. From this boiler a small steam-pipe is to be carried to the part of the building which is to be warmed. This small pipe should be pretty thick, and carefully rolled round with a bandage of flannel to the thickness of a quarter of an inch, and the boiler should be wholly covered with bricks and plastered over to keep in the heat. This smaller steam-pipe should have an area of one square inch for every six gallons of water that the boiler can boil off in an hour. Pipes of a larger size are to be laid round the room above the floor; or under the floor, if apertures be left to allow a free circulation of warmed air to enter the room. Into these larger pipes the steam is to be conducted, and in them the steam will be condensed into water, giving out its heat to the colder air of the room which is in contact with the outside of these pipes. Small leaden or tin pipes must be provided, for the purpose of bringing back this condensed water into the boiler, for which movement a gentle slope is given to the pipes. The water thus returned, being again heated in the boiler and converted into steam, is again made to ascend and give out its caloric to the room which is to be warmed.

The efficacy of this mode of heating depends on the great capacity for heat which steam possesses, a capacity equal to 1000°; that is, a pound of water at 212° will absorb a thousand degrees of heat in becoming a pound of steam. Steam will thus communicate as much heat as a mass of red-hot iron; and it will have this advantage over the iron, that it can carry this heat to a distance without a similar loss, because the heat, being latent, will not be given out until it arrive at its destination and become condensed, when the whole of its 1000° will be usefully applied.

Tredgold, Mr. Scott Russell, Dr. Arnott, and other writers on this subject have given the results of their calculations as to the quantity of steam and steam-pipe thus required. Dr. Arnott, after taking into account the loss of heat through the thin glass of windows, through the thick walls of buildings, and through various openings and crevices, arrives at the following result:—In a winter day, with the external temperature at 10° below freezing, to maintain in an ordinary apartment the agreeable and healthful temperature of 60°, there must be of surface of steam-pipe, or other steam-vessel, heated to 200° (which is the average surface-temperature of vessels filled with steam of 212°), about one foot square for every six feet of single-glass window of usual thickness; as much for every 120 feet of wall, roof, and ceiling of ordinary material and thickness; and as much for every six cubic feet of hot air escaping per minute as ventilation, and replaced by cold air. A window with the usual accuracy of fitting is held to allow about 8 feet of air to pass by it in a minute; and there should be for ventilation at least 3 feet of air a minute for each person in the room. According to this view, the quantity of steam-pipe or vessel needed, under the temperatures supposed, for a room 16 feet square by 12 feet high, with two windows, each 7 feet by 3 feet, and with ventilation by them or otherwise at the rate of 16 cubic feet per minute, would be—

For 42 square feet of glass, requiring 1 foot for 6 = 7
„ 1238 feet of wall, ceiling, &c., „ 1 foot for 120 = 10⅓
„ 16 feet per minute ventilation „ 1 foot for 6 = 2⅔
20

that is 20 feet of pipe 4 inches in diameter, or any other vessel having the same extent of surface.

Mr. Scott Russell's calculations had relation to the quantity of water and of fuel required, as well as that of the steam-pipe; and he arrives at the conclusion that a room containing 500 cubic feet of air, and exposing 400 feet of surface, may be maintained at a temperature of 20° above that of the air without—that is to say, at 60° in the inside of the room when the atmosphere is at 40° without—for a space of twelve hours, by the evaporation of two gallons of water, and at the expense of about three pounds of coal. This calculation rests on the maintenance of the required temperature so far as the room and its contents are concerned; but the change of the air requisite for a person living in the room disturbs the formula, and brings into it many new elements.

This mode of heating buildings is adopted to a large extent in Lancashire, Yorkshire, and Cheshire, in the steam-power factories. In the cotton-mills, woollen-mills, flax-mills, power-loom factories, dye-works, bleach-works, print-works, &c., the facilities for producing an uninterrupted supply of steam are so great, that the steam-heating system becomes by far the most economical that can be employed. Orrell's cotton-mill at Stockport may be taken as an exemplification of a large class of such buildings. This mill is situated on the banks of the Mersey, and occupies a ground area of 280 feet by 200 feet. It is six stories in height, and has several distinct apartments 280 feet in length each. All the preparatory processes are effected in the upper stories; while the weaving and finishing are conducted below; but all the rooms and galleries are alike heated by large steam-pipes, running the whole length of the rooms, and conveying steam from one end of the building, where the boilers are situated, which furnish not only this supply of steam, but also that required by four steam-engines employed in the mill. The steam is admitted to the heating-pipes in quantity proportionate to the coldness of the weather.

A very large structure at New York, presented to the city as a museum and lecture-room, and called the Union Building, affords a good example of the steam-heating system. There are no less than eight miles of small pipe arranged in the basement, filled with high-pressure steam. A fan-blower, twelve feet in diameter, sends a vast body of air rapidly through the pipe-rooms; and the air thus warmed finds its way into spaces beneath every floor. A hole of one inch diameter is made through the floor under every chair or seat in the lecture-hall, 2300 in number; up these holes warm air is sent in winter, and cold air in summer.

Warming by Hot Water.—The principle on which the hot-water method is founded is different from all the others which have passed under our notice. When a vessel of water is heated, the water does not become hot by the *conduction* of caloric from particle to particle, but from the ascent of heated particles from the bottom, where we suppose the heating agent to be applied, to the upper strata. This is proved from the circumstance that if heat be applied only to the surface of the water in a vessel, it is by extremely slow degrees that the lower strata becomes heated. Heat being applied to the bottom of a vessel, the lower strata of particles, becoming specifically lighter than before, ascend, while the colder particles at the surface descend to supply their place; and hence a series of ascending and descending currents is formed. Now, if, instead of having the heated water only in a vessel, it ramify also through closed tubes connected with the vessel, the ascending and descending currents may be passed through different parts of a building, besides the room where the vessel itself may be placed. The heated water, rising to 212°, or to any temperature depending on the fire to which it is exposed, gives out heat to the metallic pipe through which it passes, and this pipe again communicates heat to the air of the room. Hence the operation of this method of warming depends on the circulating, or ascensive and descensive property of heated water, by which the portions of pipe farthest removed from the fire become as much heated as those in its immediate vicinity.

Where all the apartments to be warmed are on one level, an open boiler may be used; but where it is necessary to carry the pipes to different floors of a building, some of them much above the level of the boiler, the boiler must in that case of necessity be closed. When an open boiler is employed, a pipe branches out from the upper part of the side, extends horizontally through the rooms to be warmed (without in any case rising above the level of the water in the boiler), and returns again to the boiler, which it enters at a lower level than the other. Under this arrangement a current of heated water will flow from the boiler at the upper orifice, and, after traversing the tube, return to the lower orifice. A closed boiler is, however, more extensively useful, since it enables all the stories of a building to be warmed by one apparatus. The whole system, including both tubes and boiler, is filled with water at a valve at the highest point; and when heat is applied to the boiler, a circulation ensues which speedily causes the whole length of tubing to become hot. In this form of the apparatus the temperature of the water is kept down to a moderate pitch, in order to avoid danger; but in a modification of it, called the "high-pressure" method, the boiler consists of a coil of pipe forming part of the circulating pipe, and is capable of being safely heated to such a degree that the pressure of the water within equals 1000 lbs. on the square inch. The whole system of water circulation is brought to so high a temperature, that the metal of the pipes warms the air of a large building very speedily.

Many large and important buildings are warmed on one or other of these two hot-water systems—mostly on that with the closed boiler. The hot-water apparatus put up by Mr. Perkins in the British Museum, for warming the rooms formerly used by readers, suggested the plan which is adopted for warming the present magnificent reading-room. This room is warmed by three boilers, the furnaces of which consume their own smoke. Main pipes conduct the hot water from these boilers to smaller pipes, which bring it into the room, and the water then returns by other pipes to the same boilers. There is an air-shaft which reaches the full height of the building, having windows in it to admit fresh air. There is a fan, or blower, at the bottom of the shaft. Air is forced from the shaft through valves into arched brick chambers, whence it cannot return. This air is filtered through a wire sieve, and is then conveyed up into the reading-room—not to warm it, but to keep up a supply of pure air. The doors of the room are made double, insomuch that nearly all the air that enters it comes from this shaft. There are pipes under each table, and valves above the tables to admit warm or cold air according to the season of the year. The new Houses of Parliament are also warmed by a modification of the hot-water system.

Another large structure, the warming of which may be adduced as an example of this system, is St. George's Hall, at Liverpool. Furnaces and boilers send hot water through about a mile of 4-inch pipe. A fan, worked by a 10-horse power steam-engine, draws in the external air, and drives it past the hot-water pipes. The warmed air enters the halls and courts by apertures in the walls and floors. The temperature of the pipes rarely exceeds 90°. There are 120 fire-places and flues of various kinds; but there are no chimney-pots, and no smoke is made. There are open fire-places in many of the rooms, in which coal is used that has been partially burned, but not actually coked, previously. What little smoke there is escapes, together with the vitiated air, up flues at the four corners of the hall; these flues have curved deflectors outside, and louvres inside, to shield the ascending currents from eddies of wind. There are vast air-chambers between the ceiling of the hall and the outer roof, to carry off the respired air and the products of the combustion of the gas lights.

Ventilation.—There is an important, but often neglected circumstance attending the artifical warming of buildings: namely, that the amount of fresh air, requisite under any condition for animal respiration, must be more and more increased in proportion to the fuel burned in the room; or, more correctly, there must be one portion of air to feed combustion, and another portion to aid respiration. Now, under the common arrangements of an English apartment, the open fire-place and the tall chimney draw air so rapidly in that direction, that the whole body of air in the room becomes speedily changed, provided there be an average amount of open doors, windows, crevices, &c. to yield the supply. Until modern inquirers set themselves to solve these two questions, or others analogous to them—" How many cubic feet of air are requisite for the combustion of a pound of coal ?" and, " How many cubic feet of air are respired by an average man in an hour ?"—there were no means of determining the proper amount of air necessary to be supplied in a building where *close* stoves are used, or where the methods of warming by heated air, by steam, or by hot water are adopted.

Dr. Arnott places the matter under the following form, so far as respiration alone is concerned:—" In respiration or breathing a man draws into his chest at one time about twenty cubic inches of air, and of that air a fifth part is oxygen; of which again there is converted into carbonic acid gas nearly a half. The carbonic acid, if afterwards inhaled, would be noxious to the individual. About fifteen inspirations are made in a minute, vitiating, therefore, three hundred cubic inches, or nearly one-sixth of a cubic foot, of atmospheric air, but which, mixing as it escapes with several times as much, renders unfit for respiration at least two cubic feet under common circumstances." Tredgold makes a very different estimate of the quantity of air respired in a minute, and introduces other items into his calculations. In the first place he reckons the average number of respirations per minute twenty, and the number of cubic inches of air inspired each time forty; so that the air directly vitiated amounts to eight hundred cubic inches per minute. He next takes into consideration the vapour mixed with the respired air, and the insensible perspiration always going on from the skin, and assumes that three cubic feet of air per minute will be requisite to remove these causes of impurity. Lastly, he supposes a room to contain persons in the evening, when candles, lamps, &c. are lighted, and in lieu of the air vitiated by this combustion he assumes (on what data does not clearly appear) that one-fourth of a cubic foot of fresh air per minute for every individual will be necessary to purify the atmosphere of the room on this ground. Taking all these results together, Tredgold comes to the conclusion, that when a room containing several persons is lighted to the average and customary degree, it will be necessary to supply four times as many cubic feet of fresh air per minute, as there are persons in the room; that is, four feet for each person.

This supposition, of four cubic feet of fresh air per minute for each individual in a room artificially lighted, of course involves the condition that an equal quantity of vitiated air per minute must be allowed to escape; and the inquiry naturally follows, How does this escape take place ? Carbonic acid gas is heavier than atmospheric air; but there are three circumstances which render respired air rather lighter than the general air of a room: namely, the existence in it of nitrogen and vapour, both of less specific gravity than air, and the higher temperature of the respired air than the air of a room. From all these circumstances combined, it is found that respired air ascends to the upper part of the room; and it follows that the ceiling, or some neighbouring part, is the proper place for an outlet.

In the majority of buildings erected, there is no account whatever taken of the means for insuring ventilation. The fire-places are constructed, the windows fixed, and the doors hung without a thought being paid to the means of effecting a constant change of the air contained within the apartments. But it is probable that in most English rooms, provided as they are with tolerably large open fire-places, and with doors which are frequently opened, the ventilation is sufficiently complete. The fresh air enters the room by the open window, the lower part of the open door, and any crevices which may exist at a small height from the floor; while the vitiated and specifically lighter air escapes partly up the open fire-place and chimney, partly near the upper extremity of the open doors, and partly by crevices around the doors and windows generally. In crowded rooms, however, where the amount of vitiated breath bears a much larger ratio to the cubical contents, and where the doors are generally small compared with the height of the room, the impure air cannot escape by these means, and some arrangements must be made near the ceiling for the removal of the air. These methods are chiefly of two different kinds; the one by the use of a *revolving wheel* or *fan*, and the other by the action of a *chimney* or *tube*.

We sometimes see one of the upper panes of glass removed from a window, and its place supplied by a revolving fan, as a means of ventilating the appartment. This fan or wheel is provided with radii formed like the sails of a windmill, or the blades of a screw-propeller, so that any force which sets the wheel in motion will cause a current of air to pass obliquely between them. But in this case the fan is made to revolve merely by the impulse of the air itself, and is not under the control of the inmates of a building. A more complete exemplification is presented by the arrangement of the large cotton-mills of the North. A fan-wheel, fan-ventilator, or wind-fan (for by all these names the contrivance is known), being placed in any convenient position, is set in motion by the steam-engine of a factory, and by its rotation draws out the vitiated air from a series of rooms with great rapidity. The following is one variety of wind-fan used in the factories. It consists of two cast-iron end-plates, A A, having a central circular opening, *c c c*, from the circumference of which the outline of each plate enlarges spirally, the point nearest the centre being near *d*, and that farthest off being under E (*Fig.* 1). These two parallel plates are connected by bolts, *a a a*; a mantle of sheet-iron being previously inserted into grooves cast in the edges of the end-plates so as to enclose a cavity with an elongated outlet at B, to which a pipe is attached for carrying off the vitiated air in any direction. Within this cavity a shaft, C, revolves, in bearings, *b b*, placed centrally in the frame-plates, A A, and cast in the same piece. On this shaft a boss is wedged fast, bearing five flat arms, *c c c*, to which are riveted five flat plates or wires, of the shape shown between *a* and *a* (*Fig.* 2), having a semicircular piece cut out of them on each side, about the size of the end opening. On one end of the shaft, C, beyond the box-bearing, the loose-and-fast pulleys, D, are fitted for receiving the driving-band, and for turning the wings in the direction shown by the arrow. Thus the air is driven before them out of the end orifice, B, while it enters by the side openings at *c c c* (*Fig.* 1). By the centrifugal force of the revolving wings, the air is condensed towards their extremities, and makes its escape from the pressure through the orifice, B, while it is continually drawn in at the sides by its tendency to restore the equilibrium.

Fig. 1.

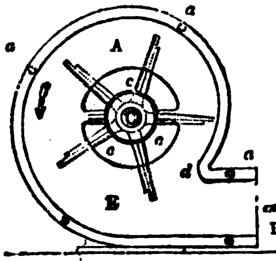
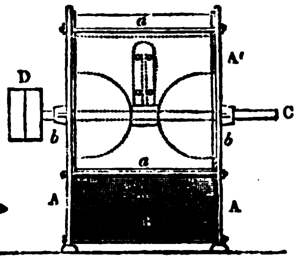


Fig. 2.



At the Reform Club-house a steam-engine works a revolving fan, capable of throwing 11,000 cubic feet of air per minute into a subterranean tunnel under the basement story; and the steam of condensation, from the small steam-engine which works the fan, supplies three cast-iron chests with the requisite heat for warming the whole building. A plan of ventilation has been adopted at the General Post-Office, in which the fan is used. The fan, worked by a steam-engine, draws fresh air down a shaft; the air is filtered through fine wire-gauze, and then sent up into all the rooms through pipes pierced with small holes.

The second mode of effecting ventilation, namely, by the use of a tube or chimney opening into the air from the upper part of an apartment, depends for its action on the ascensive power possessed by a lofty aërial column. As the " draught " of a furnace-chimney carries up the smoke, &c., more rapidly if the chimney be very lofty, so does a lofty chimney exceed a low one in carrying off vitiated air: and for the same reason, even if no chimney, properly so called, be provided, a lofty room, furnished with appropriate openings in its ceiling, will furnish a draught to carry off impure air more rapidly than a low room; and in many of our public buildings this arrangement is deemed sufficient.

Dr. Reid, when the temporary House of Commons was being prepared, introduced the system of an *artificial* draught. A circular shaft was built, 120 feet high, and from 8 to 11 feet in diameter. A large fire was maintained at the bottom of this shaft, which caused a powerful draught; and the draught sucked out all the vitiated air from the building, by a tunnel connecting the basement story with the shaft. The vitiated air in the House ascended by apertures into a space above the ceiling, and thence descended by pipes to the tunnel which conveyed it into the shaft. The experience derived from this arrangement led to many improvements in the ventilation of the present Houses. Mr. Goldsworthy Gurney here employs mechanism, by which fresh air is drawn in from some of the open courts, and after being filtered through a wire-gauze screen, is made to pass over steam-heated boxes; it is moistened by jets of spray, and enters the floors of both Houses through holes covered with horsehair cloth. In summer the air is cooled by the wet spray, and does not come into contact with any heated surfaces. Besides this mode of warming the two principal chambers, there are steam-pipes to various parts of the building. A large coke fire produces a draught, which drives the vitiated air out of openings near the ceiling.

The modern application of the two main principles of ventilation—the production of a current by a rotating fan, and by the ascensive force of heated air—are very varied. We can only notice a few of them. One of the simplest and best known is Dr. Arnott's chimney valve, for ventilating ordinary sitting-rooms. The air of a room, vitiated by breathing, smoking, &c., ascends, but cannot easily escape, because there are no openings near the ceiling; it contaminates all the air above the level of the chimney opening. A chimney valve corrects this. A hole is made from the side of the room into the chimney, near the ceiling. An iron door or valve is fixed in the opening, so nearly balanced as to open or close with great ease. When opened, the air in the upper half of the room enters by virtue of the draught in the warm chimney.

Lesure's method of ventilation, introduced in 1857, draws in cold air from the atmosphere, warms it, discharges it near the ceiling, and sends off the impure air from a room without mixing with the pure warm air. To effect this, a fire is lighted in a small stove or furnace; the products of combustion are carried at once through pipes into the chimney; and air enters through a hole in the outer wall, by a channel to a receptacle beneath the fire-place, into the interior of a casing surrounding the stove, but not in contact with any part of the fire or stove. The air becomes heated during its passage, and at the same time moistened by steam from a basin of water placed within the case; it escapes through an opening into the room, by *lateral* apertures parallel with the ceiling. As the upper parts become filled with warm air, the foul air finds its way to the fire and the chimney. In Wemyss's plan, introduced in 1859, an adjustable gridiron slide is fitted up in the wall near the ceiling, the inner side flush with the wall. The slide governs a passage into a metal chamber, fitted into a hole in the wall behind the slide. The chamber has two passages, one to admit the passage of fresh air, the other of foul. There is a ventilating fan at the outer end of the chamber. A cord easily moves the sliding valve, so as to make it open or close; and the chamber is made telescopic, to suit it to the thickness of the wall. M'Kinnel's patent ventilator, introduced in the same year, is intended to ventilate carriages and ships as well as houses and public buildings. It is planned to obviate certain evils arising from having the abduction tubes, to draw off foul air, near the roof or ceiling, and the induction tubes, for admitting fresh air, near the floor; in all such arrangements there is a cold current in the lower part of a room, productive of many inconveniences. To remedy this defect, Mr. M'Kinnel proceeds as follows. Two concentric tubes rise from the ceiling of the room to be ventilated, the inner one to a greater height than the outer. Both have access, in various ways, to the outer atmosphere. The vitiated air of the room escapes through the inner tube, while the pure air from without descends through the annular space between the two tubes. Both passages have wire gauze screens to ward off rain, soot, &c.; and valvular mechanism to regulate the currents. A lower apartment may be ventilated in a similar way, by having the ascending and descending flues in the outer walls, and a horizontal tube between the ceiling of the room and the floor of that next above it.

The ventilation of hospitals has received much attention in France and other parts of the Continent. Dr. Van Ecké introduced a system in Belgium, which has been copied in some of the French hospitals, on the recommendation of a commission presided over by Dr. Grassé. A stove called a *calorifère* is placed in the basement story. Air from the garden of the hospital descends a shaft, passes horizontally into the basement, and thence through the stove. The air warmed in the stove passes over a pan of water to imbibe moisture, and then ascends to the wards above. In warm weather the air from the garden is made to pass up into the wards without passing through the calorifère, by simply turning a regulating valve. Thus all the air admitted to the wards is derived from the garden. The warmed air enters each story at the centre of the floor, through small holes. Some of the warm air is in an *inner* tube, and ascends to the next highest story; and so on, up to the top range of rooms. The foul air rises from the four corners of each ward, up pipes to the loft, and then to a central drum or shaft. A small steam-engine works a fan to draw out the foul air more quickly. The smoke from the engine fire and from the calorifère is made to warm a mass of air carried up to the drying-room of the laundry. In England, Dr. Arnott has ventilated the York County Hospital in a peculiar way. There is an air-cylinder with a capacity of 125 cubic feet, moving up and down eight times in a minute, and connected with a beam having a central pivot. A column of water, 60 feet high, produces a pressure which forces air into the cylinder, and from the cylinder 2000 cubic feet per minute is forced into the building.

This subject, the ventilating of hospitals, is connected medically with a recent proposition by Dr. Stenhouse, to use charcoal as a ventilating filter for ships and sick rooms. The antiseptic properties of charcoal are well known. Dr. Stenhouse proposes to employ two sheets of wire-gauze, enclosing a thin layer of powdered charcoal; and to place this apparatus wherever foul air is likely to pass. In some cases it would be well to employ a ventilating fan, to force a passage of the air through the filter. Dr. Stenhouse remarks, that if a layer of coarsely-powdered charcoal were placed under the floors of kitchens and basement rooms, it might prevent, by a sort of filtration, the ascent of offensive sewer odours from beneath.

We may advert, lastly, to an inquiry made in 1859, at the instance of the General Board of Health, by a commission consisting of Mr. Fairbairn, Mr. Glaisher, and Mr. Wheatstone. Dr. Lyon Playfair was also appointed; but as he could not assist in the investigation, he did not sign the report. The inquiry was generally into the modes of warming and ventilating buildings. Experiments were made in the board-room of the General Board of Health, on the temperature of the air, walls, and floor, and on the hygrometric state of the air. Then at the Wellington Barracks, in different soldiers' rooms, heated by different kinds of open fires. Other experiments were made to determine the effect of duplicate panes of glass; and to determine the chemical and general state of the air.

Among the results at which the commissioners arrived were the following:—Smoke from almost all fires for warming rooms may be avoided. All fire-places ought to be constructed to prevent the formation of smoke at all. The ventilation of rooms ought *not* to be attempted by any peculiar form of grate; the grate ought to be devoted to the due burning of the fuel, leaving the ventilation to be achieved by other means. In all open fire-grates reflecting surfaces should be used, to increase the amount of heat radiated into the rooms. Chimney-flues should be of much smaller dimensions than is customary. The flue should not be situated in the outer wall of the house, so as to become chilled by the external air; it should be provided with a closing aperture, placed far back to increase the intensity of the combustion. Fire-brick linings should be used. Sunken ash pits and hidden ash should be provided. The grate is best placed when visible from the greatest number of places in the room; and the burning mass in it should be broad rather than deep. The commissioners agreed with Dr. Arnott, that the grate should not be so near the floor as is now customary in the better kind of houses.

The ventilation of mines is noticed under MINING.

To those who wish to study this subject in detail, we refer to the volumes on Warming and Ventilation by Tredgold, Hood, Richardson, Arnott, Sutton, Jebb, Lloyd, Burn, Bernan, Reid, and Perkins. The parliamentary Blue Books relating to the new Houses of Parliament, and to the proceedings of the Board of Health, also contain much information on the matter. A cheap, useful, and well-illustrated compendium of the whole subject will be found in Tomlinson's 'Treatise on Warming and Ventilation,' forming part of Weale's Rudimentary Series.

WARPING, a mode of producing a deposition of the earthy matter which is suspended in rivers. This causes a stirring of the water, which prevents the finer particles from being deposited. It is only necessary to produce a stagnation of the water for a few hours to have a copious deposit, leaving the water clear over it.

On the low flats which border the mouths of rivers, occasional inundations often cause a deposit which is highly fertilising. Thus the polders in Holland and Flanders have been formed of the mud of large rivers, and, being drained and kept dry by dykes and sluices, have formed the most fertile soils.

Warping is an imitation of this natural process:—A bank of earth is raised along the course of the river, so high that the floods cannot pass over it. In some part of this dyke is a sluice for the double purpose of letting in the water and letting it out at pleasure. When the tide is setting in and counteracting the natural current of the river, the sluice is opened and the water flows in by one or more channels made for the purpose of conveying it over the lower land, and covers it to the depth of high-water. The sluice is now shut, and the imprisoned water, becoming stagnant, deposits all the mud which it held suspended before. The sluice is opened at low-water, and the water is allowed to run out slowly; it leaves a coating of mud or sediment, which hardens and dries rapidly. This operation is repeated until a thickness of several inches of new soil has thus been warped, when it is allowed to dry, and is then ploughed and cultivated like any other field. It takes some time before any corn will grow on the new warp: at first it looks like barren mud; but it soon dries to a better texture, and ultimately produces very extraordinary crops. If its fertility decrease, and its surface is still below high-water mark, a slight warping, like the inundations of the Nile, immediately restores the fertility. What is curious, is the almost total absence of organic matter in the warp-soils, or rather, its intimate combination with the earths, so that it is not readily separated from them. It is neither like clay nor sand, but something between the two, soft to the touch, but not hardening into lumps when dry: neither very porous nor very retentive of moisture. The principal earth is silica, in a very fine state. It generally contains a portion of calcareous matter, probably from comminuted shells. It produces beans, oats, potatoes, and wheat in abundance, without any manure. It is admirably adapted to the growth of flax, especially when the warp is of a good depth.

The principal expense in warping is the sluice, and the canal through which the water is conducted over the land; the longer this latter is, the slower the process, as much warp is deposited in the canal, which has sometimes to be dug out. Accurate levels must be taken, or much expense may be incurred uselessly, if the water will not cover the surface to a sufficient depth.

It is of little consequence what the soil was originally; for a new soil is deposited over it. It should, however, not be too wet nor marshy: a porous soil is best, as this becomes the subsoil. All the inequalities which existed before, are obliterated by the warping, which fills up all cavities, and leaves a perfectly level surface. The fertility of warped land naturally leads to the conclusion that silica, in a very comminuted state, becomes best adapted for the roots of plants to shoot in, and to supply them regularly with the moisture necessary to their vegetation, and that their chief nourishment is derived from the atmosphere, since very little organic matter can be detected in warp, and few mineral substances besides the earths.

WARRANT. A warrant is a delegation by A, who has power or authority to do some act of that power or authority to B. Thus, a man having, of course, power to act in and manage his own concerns, may give a warrant of attorney to another to act or manage on his behalf. A sheriff who has power to arrest, &c., may give a warrant to his bailiff to act for him. A landlord who has power to make a distress upon his tenant, may give a warrant of distress to another for that purpose. A magistrate who has power to bring before him persons who are within his jurisdiction, and reasonably suspected of having committed certain offences, may make a warrant to others to do that act. A warrant, which should be in writing, ought to show the authority of the person who makes it, the act which is authorised to be done, the name or distinct description of the party authorised to execute it, and of the party against whom it is made; and in criminal cases the grounds upon which it is made. The sense in which the word "warrant" is more generally known relates to criminal matters. A justice of the peace has power within his own jurisdiction to apprehend a person whom he has seen commit an offence over which he has jurisdiction. He may also verbally direct, that is, give a verbal warrant to others to arrest such person in his own presence. He may also give a warrant in writing to apprehend in his absence such person, or any person against whom he has reasonable cause of suspicion from the information of others. The warrant should always be under the hand and seal of the justice. It should be addressed to the constable or constables, or to some private person by name, and the constable or the private person acting within the justice's jurisdiction will not be liable for any of the consequences of obeying a proper warrant. The warrant should name the person against whom it is directed. A warrant to apprehend all persons suspected, or all persons guilty, &c., is illegal; for the discretion as to pointing out the individual person to be apprehended is vested in the justice, not in the officer. The law as to this was expressly laid down by Lord Mansfield in the case of Money *v.* Leach, 3 Bur. 1742, where the warrant, being of the form called a general warrant, and which had been in use since the Revolution down to that time, directing the officers to apprehend the "authors, printers, and publishers" of the famous No. 45 of the 'North Briton,' was held to be illegal and void. The warrant should also set forth the time and place of making it, and the cause for which it is made. A warrant may be to bring the party before the justice granting it, or before any justice of the same county. A warrant of a justice of one county cannot be executed in another until it has been backed, that is, signed by some justice in that other county, and the same provision has been also enacted with respect to warrants granted in any one of the three kingdoms, and requiring to be executed in any other. But a warrant granted by one of the judges of the Court of Queen's Bench is tested in England, and may be executed in any part of the kingdom. A warrant is in force until it has been executed, if the justice granting it be still alive. An officer to whom it is addressed is indictable if he neglects or refuses to act upon it. He is justified in apprehending the party at any time, and in breaking open the doors of a house, but he ought first to make known to those within the cause of his coming, his authority, and to request their assistance. After the party is apprehended, the officer ought forthwith to carry him wherever he is directed by the warrant authorising the apprehension. Much of what has been said as to a warrant of apprehension is equally applicable to a Warrant of Commitment, which is the document by which a justice authorises a commitment of a party to prison, either to suffer a summary punishment or to await his trial. The same matters are essential as to showing the authority, the parties, the cause, and the purpose of the warrant, and these latter should appear distinctly, be lawful, and not be in the disjunctive. A Search Warrant is a document which authorises a search to be made for stolen goods.

A Warrant of Attorney is an authority by which a man authorises another to do an act for him, on his behalf, or as his agent or deputy. [Letter or Power of Attorney.] But the term is most commonly applied to cases where a party executes an instrument of that name authorising another to confess judgment against him in an action for a certain amount named in the warrant of attorney. It is generally given as a security by one who is, or is about to become, the debtor of another. The advantage of it is, that, by putting it into effect, the creditor obtains a judgment against his debtor at once, and has all the advantages of a judgment creditor, without the risk, delay, and expense of an action. There is frequently a condition attached, that it shall be defeated and become void upon the making of certain payments, or the doing of certain acts. In all such cases it is necessary that the defeasance, or condition, shall be written on the same paper or parchment as the warrant of attorney, and a copy of the whole filed in the Court of Queen's Bench within twenty-one days after the execution. Otherwise, in case of bankruptcy or insolvency of the party making the warrant of attorney, it will be void as against his assignees.

WARRANT OFFICERS are a class of important subordinate officers in the Royal Navy. They are divided into three grades,—gunners, boatswains, and carpenters—and each grade into three classes. We have already explained the duties of a gunner [Gunner, Naval], and of a boatswain [Boatswain]. The duties of a carpenter are multifarious and onerous. He has the general charge of the ship's hull and spars, &c., and is supposed to be an able shipwright, and a well-informed mechanic. The heaving down and repairing (by shifting part of the keel) of H.M.S. Formidable of 80 guns at Malta, some years since, under the suggestion and directions of a carpenter's mate, which elicited the special thanks of the Board of Admiralty, may be quoted as an instance of the nature of what is at times required of those who bear the inappropriate designation of ship-carpenter, as well as of the talent and resources to be found amongst them.

WARRANTY. 1. The doctrine of *warranty of lands* was formerly one of the most important parts of legal learning, but the effect of warranties having been gradually reduced within very small compass, the subject has now become of little practical use; still it is necessary for those who would properly understand the English law of real property to pay some attention to this difficult subject.

Warranty existed in the civil law, and was defined to be the obligation of the seller to put a stop to the eviction and other troubles which the buyer may sustain in the property purchased. By eviction is meant the loss of either the whole or a part of the property by reason of the right which another has to it. The other troubles referred to are those which, without affecting the property of the thing sold, diminish the beneficial interest of the purchaser, such as a claim to a usufruct, or a rent issuing out of the lands. This warranty was either *in law*, being that security which every seller is bound to give to a purchaser for the maintenance of his title to the property sold, though no stipulation to that effect was made at the time of the sale; or *in deed*, being that kind of particular warranty on which the seller and buyer agree. (Domat., l. 1, t. 2, s. 10.)

Warranty of lands in the English law is of feudal origin, and is derived from the obligation of the lord to defend his tenant's title against all claimants. If the tenant was evicted, the lord was bound to make him a recompense by giving him other lands of equal value. Every tenant holding of his lord time out of mind, by what was termed *homage ancestral*, was entitled to this warranty. The statute of the 18th of Edward I., commonly called the statute of Quia Emptores, which prohibited the practice of subinfeudation, and authorised the free alienation of property, put an end to the homage ancestral, and consequently to the implied warranty annexed to it. To avoid the effect of this, when the lord aliened, the tenants, before they attorned to the new lord, required a new warranty from him; and when the tenant aliened, it was with an express clause of warranty from himself. These express warranties were introduced even prior to the statute of Quia Emptores, in order to evade the strictness of the feudal law as to non-alienation without the consent of the heir; for though he might, on the death of his ancestor, have entered upon any lands aliened without his consent, the covenant of warranty descending upon the heir operated as a confirmation of the title of the grantee by obliging the heir who evicted him to yield the grantee a recompense in lands of equal value. This doctrine, it is said, was founded on the supposition that the ancestor would not wantonly disinherit his heir, who therefore was presumed to have received a recompense either in land or money which had purchased land, and that this equivalent descended to the heir, together with the ancestor's warranty.

This doctrine of warranty was the foundation of the assurance by way of common recovery [Recovery]; but the use of warranties in conveyances had long been superseded in practice before they were practically abolished by the statute 3 & 4 Wm. IV., c. 27 & 74.

All the learning upon this subject will be found in 'Coke upon Littleton,' with Hargrave and Butler's notes.

2. *Warranty of things personal.*—By the civil law an implied warranty as to the vendor's title was annexed to every sale, and in our law also a purchaser of goods and chattels may have satisfaction from the seller, who sells them *as his own* and whose title proves deficient. But the vendor is not bound to answer for the quality of the wares purchased (except in the case of articles of food, for human consumption), unless

he expressly warrants them to be sound and good, or unless he knew them to be otherwise, and has used art to disguise them, or has misrepresented them to the buyer.

No particular form of words is necessary to constitute a warranty, and a bare representation or description of the quality may amount to a warranty if there be nothing to negative such an understanding. The custom of any particular trade may establish an implied warranty between parties transacting business therein, it being presumed that the dealings of the parties were regulated by the custom in the absence of evidence to the contrary; but when there is express warranty, it cannot be affected by the custom of the trade. A sale of goods by sample is in effect a sale by warranty. A promise or warranty that the goods sold shall be of a merchantable quality is implied when the vendee had not at the time of the sale an opportunity of inspecting them, and when of course the general maxim of *caveat emptor* cannot apply. Also it seems that when a commodity is sold for a particular purpose, the seller must be understood to warrant it reasonably fit and proper for such a purpose, though at the time of sale the purchaser had an opportunity of inspection. Where there is an express warranty, written or, it seems, even verbal, the vendee is not at liberty to avail himself of representations not embodied in the contract and made by the vendor without fraud. A general warranty will not extend to defects that are plain and obvious to the senses, and require no skill to detect, it being presumed that the purchaser knew of and bought subject to them. It seems to be settled that when goods are sold expressly " with all faults," the seller is not liable in respect of latent defects, though he knew of them, unless some artifice be practised to prevent the buyer from discovering them; but even in the case of a sale with all faults, the vendor will still be liable on an express warranty against a particular defect. It has been said that there cannot be a warranty against future defects, but there seems to be no good foundation for the doctrine. It seems that a warranty ought to be given during the treaty for sale or at least before it is substantially completed, and that a warranty given after the completion of a sale is not binding for want of consideration. It has been decided that in actions upon warranty it is not necessary to offer to return the goods before bringing the action, nor even to give notice of the breach of warranty to the seller, though of course the not having done so would be a suspicious circumstance in the plaintiff's case. If there has been no offer to return the goods, the measure of damages will of course be the difference between the sum given and the real value, as ascertained either by sale or estimation. If the warranty be accompanied by an express condition to take back the goods, if found defective, and return the price, the buyer ought to return the goods within a reasonable time in order to maintain his action: and if, after an offer is made to do so, the seller refuse to receive them, they remain at his own risk.

There are certain rules which have been laid down with respect to sales of horses, one of the most common subjects of actions on warranty. The fact that what is termed a *sound* price is given for a horse, does not imply any warrant of its soundness. If at the time of the sale the horse has any disease, or has met with any accident which either does, or in its progress or results will diminish the usefulness of the animal, such a horse is unsound, and, therefore, a cough or temporary lameness which, though it may be curable and not permanently injurious, diminishes his present usefulness, is unsoundness. So any organic defect is unsoundness, and, therefore, a nerved horse cannot be considered sound. Roaring is unsoundness if it proceed from disease or organic defect; but crib-biting, it seems, does not amount to unsoundness, though it is within a warranty that a horse was free from vice. A warranty of soundness is broken if the disease or defect existed at the time of the sale, though it could not then be detected, and did not appear till some time afterwards. The question of the soundness or unsoundness of horses is one peculiarly within the province of a jury to determine, and, therefore, a court will not set aside a verdict on account of the mere preponderance of contrary evidence, nor on the ground of any peculiarity in the nature of the unsoundness proved.

WARREN. A Free Warren is a franchise which gives a right to have and keep certain wild beasts and fowls, called game, within the precincts of a manor, or any other place of known extent, whereby the owner of the franchise has a property in the game, and a right to exclude all other persons from hunting or taking it. It is laid down by Blackstone, that originally the right of taking and destroying game belonged exclusively to the king, and it is certain that this franchise, like that of a chace or park, must either be derived from a royal grant, or from prescription, which supposes a grant. The law is thus settled in the Case of Monopolies, 11 'Rep.' 87, b.

It does not appear that the crown ever had the right of granting free warren to one person over the lands of another, though such a right might be enjoyed by prescription. The right of free warren over the land of another might also arise under other circumstances, as when a man, having free warren over certain lands, aliened them, reserving the warren. (8 'Rep.' 108.)

A warren may lie open, and there is no necessity of enclosing it, as there is of a park. (4 'Inst.' 318.) The beasts of warren appear to be only hares and rabbits; and the fowls of warren are partridges and pheasants, though some add quails, woodcocks, and water-fowl. ('Terms de la Ley,' 589.) The grantee of free warren acquired thereby the right to appoint a person to watch over and preserve the game, called a warrener, who is justified in killing dogs, polecats, or other vermin which he finds disturbing or destroying the game (Cro. Jac. 45), and by 21 Edw. I., s. 2, entitled *De Malefactoribus*, every forester, parker, or warrener was authorised to kill persons trespassing in forests, parks, or warrens, who resisted and refused to render themselves.

The franchise of free warren has nearly fallen into disuse since the enactment of the modern statutes with respect to game.

WARREN, FREE. [Warren.]

WARTS, the name of small tumours or excrescences which occur on the cuticle. Like all other epidermoid tumours, they are unorganised in their origin and course. They are generally of a conical form, embrace only a small extent of surface, are hard, insensible, and in colour are usually darker than the surrounding surface. In structure they have a radiated character. Their growth is slow, and they derive their nutriment from the cutis over which they lie. The parts of the body on which these excrescences most frequently occur are the hands and face, although they are by no means confined to these localities. They are of an innocent character, and produce no ill consequences, except by pressure, when they occur in such parts as between the fingers and toes or on the eyelids.

When stimulated strongly, they generally get smaller or disappear altogether. Hence the best mode of treatment is the application of stimulants. It is however a curious fact that they often disappear under the use of the simplest remedies, when more violent ones have failed to affect them. The most effectual remedy is cutting them away. When this may be objected to, the caustic applications recommended are nitrate of silver, strong acetic acid, muriated tincture of iron, or a powder composed of subacetate of copper and sabine in equal parts, or the application of a hair-pencil dipped in sulphuric or nitric acid.

The thin integuments situated near the anus are often found to be the seat of excrescences having the character of warts. They are of all sizes, from a pea to an orange. When small, they may be removed by the application of the stimulants recommended above; and when large, they should be cut away with the knife.

WASHING-MACHINES were originally employed in connection with textile manufactures; but the Americans have effected much towards rendering them also applicable to domestic use.

In the bobbin-net district around Nottingham, washing-machines are employed in great variety; for the delicacy of the fabric renders much more care necessary than in the washing of the woven goods made in Lancashire and the neighbouring counties. The dash-wheel, in which centrifugal force is employed to wash and then to dry the goods, is much used, requiring steam power to work it. A kind of thumping machine called a *dolly* is sometimes employed; but it is almost too coarse in its action for delicate fabrics; and so likewise are those machines in which fluted rollers work in contact. One mode adopted is that of forcing a current of air through the ley or washing liquid, and thus blowing out the dirt from the cloth without any rubbing. To effect this, a vessel is provided to contain the goods; a pipe connects it with a blowing apparatus, which may consist of any kind of fan or wind-producer. The goods, slightly soaped, are steeped in soft water at a temperature of about 90° Fahr.; the vessel is covered over, and a current of air sent in from the blowing apparatus.

Mr. Cottrill's patent relates to a sort of triangular prism, two of which rotate on horizontal axes in a direction opposite to that in which yarns or woven goods are drawn through a tank; the angles of the prisms strike the goods as they pass, and thus wash them. In another machine by the same inventor, instead of prisms, two arms or cranks are employed, vibrating about an axis. Many washing-machines are modifications of the cylindrical dash-wheels described under Bleaching, and call for no detailed notice here. Some of the dash-wheels now used in the dye works, bleach works, and print works of Lancashire and Glasgow will wash 4000 pieces in a day. At the St. Nicholas Hotel in New York, washing is conducted for the visitors on a scale of surprising magnitude and completeness. A cylinder is half filled with soap and water; three or four hundred garments of linen and cotton are thrown in; the cylinder is made to revolve by a steam-engine; steam is admitted to the bottom of the cylinder, rises through the water, and escapes at the top. In doing so, the garments in the cylinder are forcibly driven up, and then a current of steam in the opposite direction forces them down again. By this process, repeated several times, and combined with the rotatory movement of the cylinder, the garments are very quickly washed. They are then gently dried in a centrifugal machine [Drying-Machines], and finally exposed to a current of hot air. The linen is said in this way to be washed in ten minutes and dried in seven, very cheaply, and without injury to the material. The Hampstead Board of Guardians adopted, in 1860, a new washing-machine, consisting chiefly of two ridged boards; the linen is pressed between the boards, slightly rubbed, turned over, slightly rubbed again, and so on about fifty times, the soapy water passing through the pores every time; no hand-rubbing is needed. After several weeks' trial, it was found that five shillings' worth of fuel, soap, and soda sufficed for the washing of one thousand articles.

Among the many curious American washing-machines recently introduced, one is the *ball* machine, in which a number of wooden balls are set in motion by a handle worked by a lever. The linen is so placed that the balls rub against it and against each other, and it is thus washed without the hand being applied to it. The credit claimed for this machine is, that the pressure being slight and temporary, fine fabrics are not injured; moreover, "it tears off no buttons." Another American machine has wooden contrivances intended to represent, in action if not in appearance, the knuckles of a laundress; the theory of the machine is, that the proper result can be obtained without wearing away human fingers.

WASTE, says Coke (Co. Litt., 53), "vastum dicitur a vastando, of wasting and depopulating;" but he gives no further definition. The notion of waste seems to be when a tenant for years, by the courtesy, by dower, or for life, so deals with land, or such things as are attached to the soil, as to destroy them or greatly damage them. Accordingly, the old action of waste lay against such tenants by him who had the immediate estate of inheritance.

Waste is either *voluntary*, which is an act of commission, or *permissive*, which is a matter of omission only. Voluntary waste chiefly consists in felling timber-trees, pulling down houses, or permanently altering any part of a house, in opening new mines or quarries, in changing the course of husbandry, and in the destruction of heir-looms. Permissive waste consists chiefly in allowing the buildings upon an estate to go to decay. It is a general rule that the waste which arises from the act of God is excuseable, as if a house falls in consequence of a tempest. But if the destruction of the house by the tempest has been owing to its being out of repair, the tenant is guilty of waste; and so he will be if he do not repair a house which has been uncovered or damaged only by a tempest. In the same manner, if the banks of a river, while in a state of proper repair, are destroyed by a sudden flood, the tenant is not answerable. (1 'Inst.,' 53 a, b.) The rule applies also to the case of a house burnt down by accident. But in these and all similar cases the tenant will still be bound to repair or rebuild, if he has entered into a general covenant to repair.

Tenants in tail, as they have estates of inheritance, are entitled to commit every kind of waste; but this power continues and can be exercised only during the life of the tenant in tail. When it is said that a tenant in tail may commit every kind of waste, the meaning is that he can do those acts to the land which tenants who have not an estate of inheritance cannot do. A mortgagee in fee in possession has a right at law to commit any kind of waste, being then considered as the absolute owner of the inheritance; but he will be restrained by a court of equity, which will direct an account of timber cut down, and order it to be applied in reduction of the mortgage debt. (2 Vern. 392.) Copyholders cannot, unless there be a special custom to warrant it, commit any kind of waste, and every species of waste not warranted by the custom of the manor operates as a forfeiture of the copyhold. (13 'Rep.,' 68.)

The original remedy for waste was that under the statute of Marlbridge, 52 Henry III., c. 24, which gave to the owner of the inheritance an action of waste against the tenant for life, in which he was entitled to recover full damages for the waste committed. But as this remedy was often found inadequate, it was enacted by the statute of Gloucester, 6 Edw. I., c. 5, that the place wasted should be recovered, together with treble damages for the injury done to the inheritance. No person was entitled to an action of waste against the tenant for life under these statutes except him who had the estate of inheritance immediately expectant on the determination of the estate for life; so that if there were an existing estate of freehold interposed between the estate for life and that of inheritance, the right of action was suspended. (1 'Inst.,' 53, b.) The action of waste had long given way to the much more expeditious and easy remedy by an action of trespass on the case in the nature of waste, which may be brought by the person in reversion or remainder for life or for years, as well as in fee, and in which the plaintiff is entitled to costs, which he could not have in an action of waste (2 Saund., 252, n. 7); and the writ of waste is now finally abolished by the 3 & 4 Wm. IV., c. 27, s. 36. It seems that there was formerly no remedy for mere permissive waste after the death of the tenant, though if the estate of the tenant was benefited by the injury inflicted, as if money was derived to it from the sale of trees cut down, an action for the value of the property might have been sustained against the executor. (Cowp. 376.) Now, however, by the 3 & 4 Wm. IV., c. 52, s. 2, remedies by action of trespass or trespass on the case are given against the executors of any deceased person for any wrong committed by him in his lifetime against the real or personal property of another within six months of his death, provided the action be brought within six months after the personal representatives have taken upon themselves the administration of the estate.

But the most complete remedy in cases of waste is that in the Court of Chancery, which, upon application to it by bill, will not only direct an account to be taken and satisfaction to be made for the damage done, but will interpose by way of injunction to restrain the commission of future waste. A court of equity will grant its assistance against the commission of waste wherever the case appears to require it, even though the plaintiff is not in a condition to maintain an action at law. The court will also grant an injunction against waste *pendente lite*; and in such cases it is not necessary that the plaintiff should wait till waste is actually committed; it is sufficient if an intention to commit waste appears, or if the defendant insists upon his right to do so.

It has long been usual, when estates for life are expressly limited, to insert a clause declaring that the tenant shall hold the lands "without impeachment of waste." These words were originally intended merely to exempt the tenant from the penalties of the statute of Marlbridge, though it has long been settled that they enable him to cut down timber and to convert it to his own use; but he may be restrained in equity from committing malicious waste so as to destroy the estate, or cutting down timber which serves for shelter or ornament to a mansion-house, or timber unfit to be felled. This is what is called the doctrine of Equitable Waste. The privileges of the tenant for life under the words "without impeachment of waste" are annexed in privity to his estate, and determine with it. Thus it seems that if a lease were made to one for the life of another without impeachment of waste, with remainder to him for his own life, he would become punishable for waste, the first estate being merged in the second. (11 'Rep.,' 83, b.)

Ecclesiastical persons, who hold lands in right of a church, are disabled from committing waste, though, like other tenants for life, they have the right to take from the land materials for necessary repairs. They may not only fell timber and dig stones for that purpose, but have even been allowed to sell timber or stone, when the money was to be applied in repairs; also, though they cannot open mines, they may work those already open. (Amb. 176.) Ecclesiastical persons may be proceeded against for waste in the civil as well as the ecclesiastical courts, as an action will lie against them for dilapidations, and may be brought by the successor to a benefice either against his predecessor or his personal representatives. And the Court of Chancery will grant an injunction against any ecclesiastical person whatsoever to stay waste in cutting down timber, pulling down houses, or opening quarries or mines on the glebe. An injunction has, indeed, been granted against waste by the widow of a rector during the vacancy of the living. (2 Bro. cc. 5, 62.) By the 56 Geo. III. c. 52, the incumbents of benefices are enabled to cut down timber on the glebe-lands for the purposes of the statute (55 Geo. III.) enabling them to exchange their parsonage-houses or glebe-lands.

Tenants in tail and tenants in fee have the inheritance in the land, and they are the real owners. Those who have less estates are in the situation of the Roman Usufructuarius. [Usufructus.]

WASTE LAND. [Burren Land.]

WATCH. [Horology.]

WATCH AND WARD is the ancient provision for the maintenance of the public peace and of property in towns: *watching* relates to the night, *ward* to the day.

The duty of keeping watch and ward no doubt prevailed in Anglo-Saxon times, although it is usually stated to have been imposed by the statute of Winchester (13 Edward I., c. 4). The words of the statute are:—"And henceforth it is commanded that watches be made as formerly they were accustomed to be; that is to say, from Ascension-day to Michaelmas-day, in every city, by six men at each gate, in every borough by twelve men, in every open town by six or four men, according to the number of inhabitants; and that they watch all the night from sunset to sunrise. And if any stranger pass by them, he shall be arrested until morning; and if [no cause of] suspicion be found, he shall go quit." Then follow provisions for delivering him to the sheriff if the watch find cause of suspicion, and for raising the hue-and-cry on him from town to town if he escape. A subsequent act (5 Edward III., c. 14) extends to the day these powers of arresting suspected persons; and in reciting the previous act, this later statute treats it as applying to the country generally; but seems to limit the power of arrest to constables. The statute 5 Henry IV., c. 3, extends to the sea-coast the provisions of the statute of Winchester, and (like it) seems only to revive an ancient custom which had fallen into disuse.

The duty of keeping watch is imposed upon every inhabitant of a town in turn, at the call of the constable. The watchman must be suitably armed, and women or infirm persons must find substitutes. Not to keep watch in his turn, or not to find a sufficient substitute, is an offence for which the party may be indicted at the sessions of the peace, and may be punished by fine and otherwise.

Another class of watchmen, having like powers and duties to the former, is that appointed for the preservation of the peace. [Constable, Police.]

WATER (HO). (*Chemistry.*) Water, as it occurs in nature, has already been treated of in the Natural History Division of this Cyclopædia; its physical properties in the three states of gas [Steam; Vapour, Opalescent]; liquid [Water, following article]; and solid [Ice]; have also been separately described in the present Division; so that it is now only necessary to consider it from what may be termed a chemical point of view.

Water is a chemical combination of the two elements oxygen and hydrogen. When a jet of hydrogen is burnt in an atmosphere of oxygen, or *vice versâ*, water is formed, and condenses on and trickles down any cool surface that may be near. A compound of hydrogen, when burned in the air, also eliminates that element in the form of aqueous vapour. A cold plate held for a few moments in or over the flame of a candle, oil-lamp, or gas-jet, is soon bedewed with moisture, which may be collected and proved to be water. Conversely, water may be made to yield up its elements. Exposed to a temperature above the melting point of platinum, it is resolved into its elements. Passed in the state of steam over red-hot iron, it parts with its oxygen to the metal, and its hydrogen is evolved as gas. Submitted to the action of the electric force, its two constituents are respectively evolved, and may be collected in quantity, from the two terminals of the battery; that from the negative pole, hydrogen, occupying twice the bulk of that from the positive pole, oxygen. A given bulk of hydrogen being only one-sixteenth the weight of an equal bulk of oxygen, it follows from the fact just mentioned that the respective proportions by weight of hydrogen and oxygen in water are one of the former to eight of the latter. Many other experiments might be described demonstrating both synthetically and analytically that water is the protoxide of hydrogen; that it contains one equivalent of hydrogen ($H = 1$) and one equivalent of oxygen ($O = 8$).

Water acts upon other bodies with four different degrees of intensity. Chemically, it unites to form, first, *hydrates;* in these the water is most intimately combined, and can only be separated in many cases by a temperature approaching redness: slaked lime is such a hydrate. Secondly, water combines with crystalline bodies, as seen in sulphate of magnesia, which contains six equivalents ($MgO, SO_3, HO + 6Aq.$), carbonate of soda, which has ten ($NaO, CO_2 + 10\ Aq.$), &c. This water is generally termed *water of crystallisation*, to distinguish it from the former, or *water of hydration*. Thirdly, water, acting chemico-mechanically, is a more or less powerful solvent for most bodies. On its uses in this respect it is scarcely necessary to enlarge. Its capacity for dissolving oxygen and carbonic acid enables it to support the life of fishes and sub-aquatic plants, and without which it would be unpleasant and mawkish as a beverage. Chlorine, sulphurous acid, and sulphuretted hydrogen gases are re-agents whose chemical value would be much restricted if they could not be obtained in the state of solution in water. Its property of dissolving solids enables it to be used as a vehicle for the conveyance of organic and inorganic matter to the tissues of animals and plants, and as an indispensable medium in nearly all arts and manufactures. When water has taken up as much of a body as it can dissolve, it is said to be saturated; and if at this point some of it be removed by spontaneous or artificial evaporation, the dissolved solid is again deposited, either in an amorphous state or in beautiful geometrical forms called *crystals*. The fourth action of water is purely mechanical; it is seen in the gradual wearing away of solid insoluble matter, and is largely concerned in the formation of the channels of streams, &c.

From what has been said regarding the solvent powers of water, both upon gaseous and solid matter, it is obvious that pure water is never met with in nature. If we trace water from the moment when it assumes the liquid condition to the time when it finally makes its way to the ocean, we find it gradually accumulating impurities of various kinds. At the moment of condensation it exerts its solvent power and absorbs gases from the air. When it falls to the earth it percolates through strata more or less soluble and more or less pervious to water, and dissolves, according to circumstances, various quantities of the solid matters which it there meets with. If the surface of the earth where it falls be very hard and insoluble, the water becomes only very slightly contaminated with solid matter. Loch Katrine, for instance, contains only 2¼ grains of solid matter in a gallon of the water; the Dee, at Aberdeen, contains 4 grains; and the Tay, at Perth, contains 5 grains. Frequently, also, when the strata through which the water percolates are pervious, supposing they are at the same time comparatively insoluble, very little solid matter gets into solution. Such is the case with the green sand formation, where the water is very free from mineral matters of a solid kind. Generally, however, water meets with more constituents than those just indicated, and the quantity varies from 5 to 50 grains per gallon. When the latter quantity is exceeded, the water frequently acquires a taste, and may be regarded as *abnormal* water. The water of the ocean is in this condition. The rivers which flow into the sea carry with them matters dissolved, and leave them there, for the solid matters are not carried back by evaporation. Therefore, the sea contains a larger proportion of these substances than is contained in the water of rivers; and we get this effect on a still more exaggerated scale when, in hot climates, rivers empty themselves into lakes which have no outlet. This is the case with the Dead Sea. The river Jordan, which is constantly flowing into it, contains 75 grains of solid matter in the gallon; and none of this matter is returned again into the atmosphere, or no practical amount: therefore, there is a constant accumulation of the saline matters going on there, and in this Dead Sea we have no less than 2600 grains of solid constituents to the gallon of water. The same effect takes place in a lake in the north of Australia, discovered a few months ago. It is highly charged with saline matters, and is known to possess no outlet. There is a similar instance in the celebrated Elton Lake in Russia, which is 11 miles long, 8 miles broad, and on an average only 15 inches deep. In summer it appears to be covered with snow, in consequence of the evaporation of the water forming a crust of saline matter. No less than 200,000 tons of salt are yearly extracted from this lake.

In addition to these mineral and saline constituents, water also dissolves certain organic substances, so that we may classify the impurities contained in water as *mechanical*, or those that are merely suspended in the water mechanically, and not dissolved, *saline* impurities, and *organic* impurities. We will consider these separately.

First, as regards *mechanical* impurities. They consist, in the first place, of mineral substances which are usually innocuous, and have no effect upon the drinker. Next we have vegetable or animal matters, which are generally of an exceedingly noxious character; and then we have living organisms, which perhaps attract the attention of the water-drinker more than the other substances contained in the water. These organisms consist of animalcula and animals of a larger size. We have in the New River water twenty-six species of these animals, in the Thames water twenty-nine species; twenty-four species have been detected in the West Middlesex water, and so on, varying in number in different waters. It has been stated that some of these little animals are very deleterious to health, but this has not been at all clearly made out. Looked at from a chemical point of view, they are exceedingly useful in the water, especially if it be at all impure. Each little animal is a small furnace, which occupies itself in consuming the organic matter, and converting it into its ultimate inorganic compounds—carbonic acid, water, and ammonia, or nitric acid. They feed upon the dead organic matter in the water, and remove it far more readily than it would be removed by the oxidising property of the air. It is, of course, desirable to remove them before the water is used as a beverage, and this can be done by filtration. The animals themselves cannot pass through the filter, but the ova can. This fact has an important bearing upon the storing up of water, and will be alluded to again presently.

We come now to the *saline* impurities. The nature of these will be readily seen by an inspection of the following diagram.

Solid Constituents contained in One Gallon of various Waters supplied to Towns.

	New River Company.	East London Company.	Kent Water Company.	Thames Ditton and Gnd. Junction Co.	Farnham.	Watford.	Loch Katrine.	Aberdeen.	Liverpool.	Manchester.
Carbonate of lime . . .	7·82	10·16	7·02	11·79	·23	16·13	..	·85	·76	..
Sulphate of lime	3·23	2·33	11·03	3·06	1·31	..	·38	·12	1·	3·57
Nitrate of lime . . .	·02	·72	·07	·27	Trace	·28	..	..	..	..
Carbonate of magnesia . .	1·09	1·51	3·42	1·27	·64	·75	·15	..	·11	..
Sulphate of magnesia . .	..	..	..	..	..	..	..	·32	..	1·55
Chloride of magnesium . .	..	..	..	..	..	..	..	..	..	·13
Chloride of sodium . . .	1·73	1·76	3·50	1·10	·93	1·01	·45	·67	1·56	1·02
Sulphate of soda	1·49	·94	..	..	·07	1·31	·28	..	..	..
Chloride of potassium . .	..	..	..	·67	..	..	..	..	..	·57
Sulphate of potash . . .	1·11	1·25	·70	·17	·43	·44	Trace	..	..	..
Iron alumina and phosphates .	Traces	·47	Traces	·09	·88	..	Traces	·08	·24	·75
Silica	·50	·62	·76	·62	·99	1·59	Trace	·14	·15	·88
Organic matter	2·79	4·12	2·61	2·20	1·78	1·26	·82	1·82	1·40	1·25
	19·78	23·88	29·55	21·33	7·26	22·72	2·08	4·00	5·42	9·72

The Farnham water is from the green sand: it has been suggested as a supply for London. That from Loch Katrine is perhaps purer than the water supplied to any town in the United Kingdom. The Manchester water can always be drawn from the pipes, the supply being continuous, instead of intermittent, and this is now the case in nearly all large towns except London.

Some of these constituents are termed *earthy salts*, and some of them are *alkaline salts*. Carbonate of lime, sulphate of lime, and nitrate of lime, carbonate of magnesia, and, occasionally, chloride of calcium and chloride of magnesium, are salts of the alkaline earths; others are alkaline salts.

The property of "hardness" in water is due to the first of these classes of constituents—to the alkaline earths—the lime and magnesia salts present in the water. Hard water may be defined as a water capable of decomposing a considerable quantity of soap, and forming with the soap an insoluble precipitate. These salts of lime combine with the stearic acid, and form an insoluble stearate of lime, the curdy matter which is produced by washing in such waters. This stearate of lime is of a greasy nature; it is precipitated in, and fills up, the pores of the skin; no amount of washing in hard water can thoroughly remove it; and hence the skin can only be perfectly cleansed in rain-water, in softened hard water, or, in fact, in water that does not contain soap-decomposing matters.

Of the above constituents, the carbonates of lime and magnesia are the only ones not soluble in pure water: they are kept in solution by free carbonic acid [Calcium, *Carbonate of*]. The amount of hardness possessed by waters varies considerably: it is readily ascertained by the Soap-Test. The mode of softening waters is referred to under Calcium, *Carbonate and Sulphate of*. The only perfect method of removing fixed matter from water is, of course, distillation; indeed, this process is carried out on board some of our ships, the water being subsequently aërated for drinking purposes. On land, however, other less expensive processes are available.

The *organic* impurities contained in solution in water are of animal and vegetable origin, the former being most objectionable. The animal matter contains nitrogen, and is constantly undergoing a fermentive change. Water in this state is highly dangerous to health, and should be carefully avoided. Unfortunately, no test, short of rigid analysis, can be relied upon for detecting this animal matter. Solution of permanganate of potash is decomposed and decolourised by it, and therefore water that discharges the colour from much of that reagent should be viewed with suspicion.

One other possible contamination of water must be noticed: it is lead. Fortunately for most reasons, but unfortunately for some others, water that contains an appreciable quantity of salts does not, as a general rule, act upon lead. Pure distilled water acts very rapidly upon it, but water that is in any degree hard does not usually affect it. Lead can be easily detected in water by the blackening which occurs on passing sulphuretted hydrogen gas through the water. This effect is not, however, produced if only a very small quantity of lead be present. In that case the water, after the passage of the gas, should be set aside for twenty-four hours, when the sulphuretted hydrogen will have become decomposed, and the deposited sulphur will have a dark-brown or black colour if lead be present. It has been suggested to tin the inside of lead pipes—water not acting upon tin; but wherever water comes in contact with both metals, as at a joint or flaw, a voltaic action is set up, and the solution of the lead is facilitated instead of prevented.

Estimation of Water.—This is accomplished either by noting the loss which a body suffers on being heated, or by expelling and weighing the water evolved. If the constitution of the body is well known, the former method is sufficient; if not, the latter process is had recourse to.

Analysis of Normal and Abnormal Waters.—Of all special chemical operations this is one of the most tedious and difficult. Usually a large number of acids and bases are simultaneously present, and being all in solution, cannot be so readily separated as those of perhaps a less complex substance containing both soluble and insoluble matters. Gaseous constituents must generally be determined at the source of the water. The total amount of fixed matter is ascertained by evaporating a known bulk of the water, and weighing the residue after drying at 212° Fahr. If organic matter be present, the residue, dried at 300° Fahr., will char on being ignited; air having access, the carbon will burn off, and the difference in weight, before and after ignition, will give some idea of the amount of that organic matter. The residue may then be quantitatively analysed in the same manner as any other mixture of solids, or separate portions of the water may be used for the purpose. The arrangement of the results of a water analysis depends upon the judgment of the operator. The actual amounts of each ingredient, without reference to arrangement, should first be given, inasmuch as the state in which they naturally exist is liable to alteration from change of temperature and dilution after rain, &c. Moreover, as there are at present no data by which to determine the normal condition of the acids and bases, several systems of arrangement exist; and if the amount of each acid and base were not given, the analyses of a water by two different chemists would appear to differ widely when, perhaps, they closely agree.

WATER, in its physical relations. In the preceding article the chemical history of water is briefly reviewed, and such of its properties are described as depend, primarily, on the nature and activity of the molecules of which it is constituted. We now proceed to treat of some of those properties of water which are exhibited by masses of it, whether in its liquid, aëriform, or solid state; those which render it a subject of physics or natural philosophy; omitting, however, of course, such properties as it possesses in common with other bodies in the corresponding states of aggregation, respectively, and which have been considered in the articles Hydrodynamics; Hygrometry; Mechanics; Pneumatics, &c.

The three states of aggregation in which water, like all kinds of ponderable matter, as we have reason to believe, can exist, are all equally natural; though, as in the case of every other substance also, we are inclined to regard that condition as the most natural in which it is most commonly and obviously subject to our observation. This, with respect to water, is the liquid, as with all metals but one it is the solid, and with chlorine, ammonia, and other elementary as well as compound substances, it is the aëriform state; omitting here any reference to those gaseous bodies which have not yet been reduced to another state of aggregation.

We begin with the physical properties of water in the solid form, considering, first, those which it manifests to sensible observation.

In the article Ice the property is described, in virtue of which two portions of that substance in a moist state, when brought into contact, become one. That such is the fact has of course been known from time immemorial, but it had always been referred, without inquiry, to the freezing effect upon water of ice at a lower temperature [Hail], and had never been made a subject of scientific investigation until Dr. Faraday called attention to its nature and philosophical importance on the 7th of June, 1850, at one of the Friday evening meetings of the members of the Royal Institution of Great Britain (Albemarle Street, London); assemblies in which, from the year 1825 downwards, so many new facts and applications in science and new interpretations of facts have for the first time been publicly made known, or first publicly demonstrated by experiment. To this property of ice the term regelation was afterwards applied by Professor Tyndall, in a paper 'On the Structure and Motion of Glaciers,' by himself and Professor Huxley, read before the Royal Society on January 15, 1857 ('Proceedings,' vol. viii. p. 331), and published in the 'Philosophical Transactions' for that year. In this paper Professor Tyndall describes some experiments illustrative of the practical consequences of regelation, and of their manifestation on the great scale in nature. The entire subject forms so important a part of the history of water in its solid condition, that it is requisite to return to it here.

In the article Ice we noticed Professor Tyndall's conclusion that the plasticity of ice at 32°, in mass, arising from fracture and regelation, in continued and indefinite succession, imparts to it a deceptive semblance of viscosity, which it really does not possess. By virtue of this process, in his experiments, spheres of ice were flattened into cakes, and squeezed into transparent lenses. A straight prism six inches long was passed through a series of moulds augmenting in curvature, and finally came out bent into a semi-ring. A lump of clear ice placed in a hemispherical cavity, and pressed upon by a protuberance not large enough to fill the cavity, was converted into a hard transparent cup. In the experiments with the prism, four moulds, gradually augmenting in curvature, were made use of in succession. In passing suddenly from the shape of one to that of the other the ice was fractured, but the pressure brought the separated surfaces again into contact, and caused them to (regelate) freeze together, thus restoring the continuity of the mass. The fracture was in every case both audible and tangible—it could be heard and it could be felt. A series of cracks occurred in succession as the different parts of the ice-prism gave way, and towards the conclusion of the experiment the crackling in some instances melted into an almost musical tone.

These facts have been applied by Professor Tyndall to explain the phenomena of the motion of glaciers. [Glaciers, in Nat. Hist. Div.] This is a most important subject: the very introduction into the philosophy of glaciers of the principle of regelation, "without which," Professors Tyndall and Huxley remark, "it may be doubted whether the existence of a glacier would be at all possible," and the relation of which to glacier action the former was the first to discover, opens in itself a new field of investigation. For the details of this application we must refer to the original paper; but the following is a summary view of the subject, derived partly from that and partly from a more brief account given in the 'Proceedings' of the Royal Institution, vol. ii. p. 822.

All the phenomena of motion in glaciers, on which the idea of the viscosity of ice has been based, are brought by such experiments as those recited above into harmony with the demonstrable properties of ice. The glacier valley is a mould through which the ice is pressed by its own gravity, and to which it will accommodate itself, while preserving its general continuity, as the "hand-specimens" (to use a term familiarly applied to rocks) do to the moulds made use of in the experiments. Two confluent glaciers unite to form a single trunk, by the regelation of their pressed surfaces of junction. Crevasses are closed up, and the broken ice of a cascade, such as that of the Talèfre or the Rhone, is recompacted to a solid continuous mass. "But if the glacier accomplish its movement in virtue of the incessant fracture and regelation of its parts, such a process will be accompanied by a crackling noise, corresponding in intensity to the nature of the motion, and which would be absent if the motion were that of a viscous body. It is a well-known fact that such noises are heard, from the rudest crashing and quaking up to the lowest decrepitation, and they thus receive a satisfactory explanation.* It is manifest" also "that the continuity of the fractured ice cannot be completely and immediately restored after fracture. It is not the *same* surfaces that are regelated, and hence the coincidence of the surfaces cannot be perfect. They will inclose for a time *capillary fissures*, and thus the above theory accounts satisfactorily for the known structure of glacier-ice. Professor Tyndall made an experiment on this point in which, by a gradually increasing pressure, he produced in ice fissures of this description accurately resembling those made evident by the infiltration experiments of M. Agassiz in the glacier of the Aar.

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* The sounds sometimes heard during the appearance of the Polar Lights, and supposed to be produced by them [Terrestrial Light], have been referred by Humboldt to the mechanical changes continually going on in the ice-fields and packs of the regions in which those lights, in their most extensive and brilliant development, have been principally observed. Many of these changes must be identical with those of glaciers; and in the facts and reasoning adduced by Professor Tyndall, as above, we probably have the final explanation of this disputed subject.

Since the publication of Dr. Tyndall's researches, and that of the papers by Principal (late Professor) James D. Forbes and Professor James Thomson, the contents of which were stated in the former article, Dr. Faraday has entered into a new experimental investigation of it, which has appeared in the 'Proceedings' of the Royal Society, vol. x. p. 440–450, under the title of 'Note on Regelation,' in which he has also more fully described that property than in his previous papers. Of the new facts he has observed, and of the conclusions he has founded upon them, the following are the most important.

"Two pieces of thawing ice if put together adhere and become one; at a place where liquefaction was proceeding congelation suddenly occurs. The effect will take place in air, in water, or in vacuo. It will occur at every point where the two pieces of ice touch, but not with ice below the freezing point, that is, with dry ice, or ice so cold as to be everywhere in the solid state."

"Though some might think," Dr. Faraday resumes, "that Professor [J.] Thomson, in his last communication [ICE, col. 816], was trusting to changes of pressure and temperature so inappreciably small as to be not merely imperceptible, but also ineffectual, still he carried his conditions with him into all the cases he referred to, even though some of his assumed pressures were due to capillary attraction, or to the consequent pressure of the atmosphere only."

In order to exclude all pressure of the particles of ice on each other due to capillary attraction or the atmosphere, Dr. Faraday prepared to experiment altogether under water, arranging a bath of that fluid, maintained at 32° Fahr., which by the method he employed it could be for a week or more. [THAW.]

Two similar blocks of good Wenham-lake ice were placed in the water with their opposed faces about two inches apart, each being moored to a particular place by woollen thread attached to pieces of lead, so that they were sunk entirely under the surface of the ice-cold water. If brought near to each other and then left unrestrained, they separated, returning to their first position with considerable force. If brought into the slightest contact, regelation ensued, the blocks adhered, and remained adherent, notwithstanding the force tending to pull them apart. They would continue thus, even for twenty-four hours or more, until they were purposely separated, and would appear (by many trials) to have the adhesion increased at the points where they first touched, though at other points of the contiguous surfaces a feeble thawing action went on, causing a dissection of the ice, developing its mechanical composition, and showing it to consist of layers of greater and less fusibility, horizontally disposed in the ice whilst in the act of formation. "In this case, except for the first moment, and in a very minute degree, there was no pressure, either from capillary action or any other cause. On the contrary, a tensile force of considerable amount was tending all the time to separate the pieces of ice at their points of adhesion;" where still the adhesion went on increasing. Arrangements were next made to ascertain whether anything like soft adhesion occurred, such as would allow slow change of position without separation during the action of the tensile force. It was found that not the slightest motion of the blocks in relation to each other took place in the thirty-six hours during which the experiment was continued. "This result, as far as it goes, is against the necessity of pressure to regelation, or the existence of any condition like that of softness or a shifting contact."

Torsion force was then employed as an antagonist to regelation. The ice-blocks being separate, were adjusted in the water so as to be parallel to each other, and about 1¼ inch apart. If made to approach each other on one side, by revolution in opposite directions on vertical axes, a piece of paper being between to prevent ice-contact, the torsion force set up caused them to separate when left to themselves; but if the paper were away, and the ice pieces were brought into contact, by however slight a force, they became one, forming a rigid piece of ice, though the strength was, of course, very small, the point of adhesion and solidification being simply the contact of two convex surfaces of small radius. It was found, also, that there was no more tendency to a changing shape than in the case before examined. If the separating force were increased, but unequally, as respects the two pieces, then the congelation at the point of contact would give way, and the pieces of ice would move in relation to each other. Yet they would not separate, though the torsion force employed was constantly tending to separate them. If a slip of wood, applied to change the mutual position of the two pieces of ice without separating them, were retained for a second undisturbed, then the two pieces of ice became fixed rigidly to each other in their new position, and maintained it when the wood was removed, but under a state of restraint; and when sufficient force was applied, by a slight tap of the wood on the ice to break up the rigidity, the two pieces of ice would re-arrange themselves under the torsion force of their respective threads, yet remain united; and, assuming a new position, would in a second or less again become rigid, and remain inflexibly conjoined as before. By managing the continuous motion of one piece of ice, it could be kept associated with the other by a flexible point of attachment for any length of time, could be placed in various angular positions to it, could be made (by retaining it quiescent for a moment) to assume and hold permanently any of these positions when the external force was removed, could be changed from that position into a new one, and, within certain limits, could be made to possess at pleasure and for any length of time either a flexible or a rigid attachment to its associated block of ice. In observing these states, convex surfaces of contact are necessary, so that the contact may be only at one point. If there be several places of contact, apparent rigidity is given to the united mass, though each of the places of contact might be in a flexible, and, so to say, adhesive condition. "It is not at all difficult to arrange a convex surface, so that, bearing at two places only on the sides of a depression, it should form a flexible joint in one direction, and a rigid attachment in a direction transverse to the former."

The following are Dr. Faraday's inductions from these results, which cannot be abridged:—"So regelation includes a flexible adhesion of the particles of ice, and also a rigid adhesion. The transition between these two states takes place when there is no external force like pressure tending to bring the particles of ice together, but, on the contrary, a force of torsion is tending to separate them; and, if respect be had to the mere point of contact on the two rounded surfaces where the flexible adhesion is exercised, the force which tends to separate them may be esteemed very great. The act of regelation cannot be considered as complete until the junction has become rigid, and therefore I think that the necessity of pressure for it is altogether excluded. No external pressure can remain (under the circumstances) after the first rigid contact is broken. All the forces which remain tend to separate the pieces of ice; yet the first flexible adhesions and all the successive rigid adhesions which are made to occur are as much the effects of regelation as those which occur under the greatest pressure."

"The phenomenon of flexible adhesion under tension looks very much like sticking and tenacity; and I think it probable that Professor Forbes will see in it evidence of the truth of his view. I cannot, however, consider the facts as bearing such an interpretation; because I think it impossible to keep a mixture of snow and water for hours and days together without the temperature of the mixed mass becoming uniform; which uniformity would be fatal to the explanation. My idea of the flexible and rigid adhesion is this:—Two convex surfaces of ice come together; the particles of water nearest to the place of contact, and therefore within the efficient sphere of action of those particles of ice which are on both sides of them, solidify; if the condition of things be left for a moment, that the heat evolved by the solidification may be conducted away and dispersed, more particles will solidify, and ultimately enough to form a fixed and rigid junction, which will remain until a force sufficiently great to break through it is applied. But if the direction of the force resorted to can be relieved by any hinge-like motion at the point of contact, then I think that the union is broken up among the particles on the opening side of the angle, whilst the particles on the closing side come within the effectual regelation distance; regelation ensues there, and the adhesion is maintained, though in an apparently flexible state. The flexibility appears to me to be due to a series of ruptures on one side of the centre of contact, and of adhesion on the other,—the regelation, which is dependent on the vicinity of the ice surfaces, being transferred as the place of efficient vicinity is changed. That the substance we are considering is as brittle as ice, does not make any difficulty to me in respect of the flexible adhesion; for if we suppose that the point of contact exists only at one particle, still the angular motion at that point must bring a second particle into contact (to suffer regelation) before separation could occur at the first; or if, as seems proved by the supervention of the rigid adhesion upon the flexible state, many particles are concerned at once, it is not possible that all these should be broken through by a force applied on one side of the place of adhesion, before particles on the opposite side should have an opportunity of regelation, and so of continuing the adhesion."

The changes of temperature and pressure in the process of regelation, as here investigated, Dr. Faraday thinks, are too infinitesimal to go for anything; and in illustration of this opinion, he describes an experiment. For this, however, as well as for the manipulation of the experiments in general, we must refer to his paper; but an addendum to it we now cite, as it details an easy method of examining the various phenomena of regelation which have been ascertained. "Take a rather large dish of water at common temperatures. Prepare some flat cakes or bars of ice, from half an inch to an inch thick, render the edges round, and the upper surface of each piece convex, by holding it against the inside of a warm saucepan cover, or in any other way. When two of these pieces are put into the water they will float, having perfect freedom of motion, and yet only the central part of the upper surface will be above the fluid; when, therefore, the pieces touch at their edges, the width of the water-surface above the place of contact may be two, three, or four inches, and thus the effect of capillary action be entirely removed. By placing a plate of clean dry wax or spermaceti upon the top of a plate of ice, the latter may be entirely submerged, and the tendency to approximation from capillary action converted into a force of separation. When two or more of such floating pieces of ice are brought together by contact at some point under the water, they adhere; first with an apparently flexible, and then with a rigid adhesion. When five or six pieces are grouped in a contorted shape, as an S, and one end piece be moved carefully, all will move with it rigidly; or, if the force be enough to break through the joint, the rupture will be with a crackling noise, but the pieces will still adhere, and in an instant become rigid again. As the adhesion is only by points, the force applied should not be either too powerful or in the manner of a blow. I find a piece of paper, a small feather, or a camel-hair brush applied under the water very convenient for the purpose. When the point of a floating wedged-shaped piece of ice is brought under water against the corner or side of another floating piece, it sticks to it like a leech; if, after a moment, a paper edge be brought down upon the place, a very sensible resistance to the rupture at that place is felt. If the ice be replaced by like rounded pieces of wood or glass, touching under water, nothing of this kind occurs, nor any signs of an effect that could by possibility be referred to capillary action; and finally, if two floating pieces of ice have separating forces attached to them, as by threads connecting them and two light pendulums, pulled more or less in opposite directions, then it will be seen with what power the ice is held together at the place of regelation when the contact there is either in the flexible or rigid condition, by the velocity and force with which the two pieces will separate when the adhesion is properly and entirely overcome."

In Dr. Faraday's second published notice of regelation ('Exp. Res. in Chem. and Phys.,' pp. 380, 381), he had adduced the growth of crystals of camphor and of iodide of cyanogen, by the deposition of solid matter upon them from an atmosphere unable to deposit like solid matter upon the surrounding glass, except at a lower temperature; and that of crystals in a solution, by the deposition of solid matter upon them which is not deposited elsewhere in the solution, to illustrate the extension of the principle of action which is manifested in regelation. In his reasoning on the nature of that principle, he also rested on the fact, that ice has the same property as camphor, sulphur, phosphorus, metals, &c., which cause the deposition of solid particles upon them from the surrounding fluid, that would not have been so deposited without the presence of the previous solid portions.

But the further experimental inquiry to which he has now subjected the phenomena of regelation, appears to have conducted him to a view of them which is not altogether reconcileable with his previous inferences respecting the extension of the principle. He now asks, "Is this remarkable property peculiar to water, or is it general to all bodies? In respect of water, it certainly seems to offer us a glimpse into the joint physical action of many particles, and into the nature of cohesion in that body when it is changing between the solid and liquid state. I made some experiments on this point;" which he proceeds to relate.

The metals bismuth, tin, and lead did not present the slightest trace of an action corresponding to regelation. Melted nitre appeared at times to show traces of the power; but, on the whole, Dr. Faraday is inclined to think that the effects observed resulted from the circumstance that the solid rods experimented with had not acquired throughout the freezing temperature. Nitre, however, he remarks, "is a body which, like water, expands in solidifying; and it may possess a certain degree of this peculiar power." Glacial acetic acid, he finds, is not merely without regelating force, but actually presents a contrast to it.

"Many results were tried (without much or any expectation), crystals of them being brought to bear against each other by torsion force, in their saturated solutions at common temperatures. In this way the following bodies were experimented with:—Nitrates of lead, potassa, soda; sulphates of soda, magnesia, copper, zinc; alum; borax; chloride of ammonium; ferro-prussiate of potassa; carbonate of soda; acetate of lead; and tartrate of potassa and soda; but the results were all negative."

Dr. Faraday's "present conclusion, therefore, is that the property' of regelation "is special for water, and that the view" he has "taken of its physical cause"—"that a particle of water, which could retain the liquid state whilst touching ice only on one side, could not retain the liquid state if it were touched by ice on both sides, but became solid, the general temperature remaining the same"—"does not appear to be less likely now than at the beginning of this short investigation, and therefore has not sunk in value among the three explanations given," namely, his own and those of Professor James Thomson and Principal Forbes, respectively, which have been stated in our former account of this subject.

In the 'Proceedings of the Royal Society' for May 2, 1861 (vol. xi., pp. 198–204), appears a note by Professor James Thomson, in which he states that he still adheres to the explanation of Principal Forbes's experiment, cited from a former paper by him in our article ICE, as mainly correct, though admitting of modification in reference to a point which seems to him to be as yet rather obscure:—"the influence, namely, of the tension in the ice due to its own weight, which makes it *not* be subject internally to simply atmospheric pressure." Professor Thomson also points out some additional conditions, almost necessarily present in the experiment, which, under his view of the plasticity of ice, would act in conjunction with those originally adduced, and would increase the rapidity of the union. But his principal object in this communication is to dissent from the interpretation given by Professor Faraday of his recent experiments, as above, and to express the opinion that they are in perfect accordance with, and tend to confirm, his own theory, and its application to the various observed cases of the union of two pieces of moist ice when placed in contact. This he does, after describing Faraday's results, in these terms:—"My view of the phenomena of these experiments is as follows: the first contact of the two pieces of ice cannot occur without impact, and consequent pressure; and, small as the total force may be, its intensity must be great, as the surface of contact must be little more than a geometrical point. This pressure produces union by the process of melting and regelation described by me in previous papers. On the application of the forces from the two feathers, at one side of the point of contact, tending to cause separation, the isthmus of ice formed by the union of the two pieces, comes to act as a tie or fulcrum subject to tensile force; and, consequently, a corresponding pressure will occur at the side of the isthmus far from the feathers, and that pressure will effect the union of the ice at the side where it occurs. The tensile force, it may be readily supposed, tends to preserve the isthmus, internally at least, in the state of ice, whatever may be its influence on the external molecules of the isthmus, and to solidify such water as, having occupied pores in the interior during previous compression, may now, by the linear tension or pull, be reduced in cubical pressure or hydrostatic pressure, because the melting-point of wet ice is raised by diminution of pressure of the water in contact with it. The pull applied to the isthmus thus appears to put it out of the condition in which my theory has clearly indicated a cause of plasticity, and, I presume, makes it cease, or almost entirely cease, to be plastic. I believe no plastic yielding of ice to tension has been discovered by observation in any case, and I think there are theoretical reasons why ice should be expected to be very brittle in respect to tensile forces. The isthmus then being supposed devoid of plasticity at its extended side, ultimately breaks at that side when the opening motion caused by the feathers has arrived at a sufficient amount to cause fracture; and the ice newly formed on the compressed side comes now to act as a tie, instead of the part which has undergone disruption, and holds together the two pieces of ice, or serves as a fulcrum under tension to communicate a compressive force to the points of the two pieces of ice immediately beyond it; and so the rolling action with a constant union at the point of contact goes forward. It is to be observed, that the leverage of the forces applied by the feathers is so great, compared with the distance from the fulcrum or tensile part of the isthmus, to the compressed part in process of formation at the other side as that the compression may usually be considered almost equal to the tension; and the tension in the extended part cannot be of small intensity, being sufficient to break that side of the isthmus. In the experiments which gave flexible adhesion *seemingly* under tension, it is not to be admitted that tension was really the condition under which the ice existed at the places where the union was occurring. To apply a simple disruptive force to the whole isthmus of ice, it would be necessary to take very special precautions in order to arrange that the line of application of the disruptive forces should pass through the point of contact of the two pieces. If that were done, and the forces were gradually increased till the cohesive strength of the isthmus were overcome, it is clear that the two pieces of ice would separate altogether, and there would be no flexible adhesion; but the flexible adhesion, when it occurs, is essentially dependent on the existence of an intense pressure at the side of the isthmus remote from the line of the externally applied disruptive forces, or of the single force applied in some of the experiments to one only of the pieces, and resisted by the inertia of the other."

While Dr. Faraday was engaged in the experimental corroboration of the cause to which he had originally assigned regelation, and in the limitation of the inferential views of its extension which he had first taken, a less conspicuous inquirer had been led to found upon those views and upon a known fact in the physical history of glass, a theory of the universality of regelation. This had been indicated, and the fact in question stated, at the end of our former account of the subject in the article ICE. In the 'Proceedings of the Royal Society' (vol. x., pp. 450-460), Dr. Faraday's 'Note on Regelation' is followed by Mr. Brayley's 'Notes on the Apparent Universality of a Principle analogous to Regelation; on the Physical Nature of Glass; and on the Probability of the Existence of Water in a state analogous to that of Glass.'[*] In the first of the three 'Notes' of which Mr. Brayley's paper consists, the view of the subject taken in ICE (col. 817) is resumed in greater detail, the facts there mentioned being regarded as "indicating the existence of a condition of matter which may be termed arrested liquidity, but yet is not, in the most perfect sense, solidity." It is assumed also to be highly probable that the process by which two plates of polished plate-glass become one is, in reality, analogous to that of regelation in ice, and finally dependent on the same principles, whatever their true character may be conceived or shall ultimately be determined to be. Facts are stated, from which it is inferred that the state of the interior portions of a plate of plate-glass is similar to that of glass in general at certain temperatures much below its fusing point, when it presents such remarkable characters of plasticity, tenacity, and ductility. These facts are stated to recall the view taken by Person, and adopted by Principal Forbes [ICE, col. 816; THAW], of the similarity of the liquefaction of ice to that of fatty bodies or of the metals, "which in melting pass through intermediate stages of softness or viscosity;" and it is remarked, also, that Sir J. F. W. Herschel, when he terms regelation "a sort of welding" [HAIL, col. 603], appears to concur in this view. Mr. Brayley asks, in conclusion of this part of the subject, "Are all cases of the union of two apparently solid surfaces of the same substance by cohesive attraction cases of melting and regelation, an infinitesimally thin film of liquid being momentarily produced and as instantly solidified?"; and having in discussing the philosophy of the union of two surfaces of glass followed the reasoning of Professor J. Thomson, on the cause of regelation, he states, notwithstanding, that he wishes to be understood as not adopting, exclusively, any existing theory on the subject. Admitting the operation of cohesive attraction and consequent pressure in the first instance, the phenomenon, with respect to glass, it is shown, readily admits of explanation by the original view of Mr. Faraday with respect to ice. [ICE, col. 814.]

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[*] These notes were received by, and read to, the Royal Society on the 26th of April, 1860, after Dr. Faraday had given an oral account, experimentally illustrated, of the contents of his own 'Note,' which had been received in the preceding month.

The object of Mr. Brayley's second 'Note' does not, strictly belong to the subject at present before us, but to preserve the sequence of the whole inquiry in its bearing on the physics of water, we may mention that he finds reason to regard the molecular constitution of glass as being analogous to that of "water cooled below the freezing point, but still remaining liquid, until by a tremor, or the percussive contact of a solid body, or the mere contact of a crystal of ice, its temperature rises to 32°, and it becomes ice," or to that of a saturated solution of salt in hot water. "If so," he remarks, "glass will be a substance in which this state of arrested liquidity, or potential solidity, is permanent." Instructive parallels are also noticed between the crystallisation of water and that of glass and some other bodies, which are presented by the experiments of Gregory Watt, and Faraday.

It is observed in the concluding 'Note,' that "No crystalline body has been longer or more extensively subject to human observation than crystallised water, or ice. Its natural history and properties, as science has advanced, have been investigated with increasing generality and precision; and they have finally become objects of that systematic and exact research which characterises the present era of physical inquiry. . . . . A most remarkable deficiency, however, still remains, apparently, in our knowledge of this substance: *water in the vitreous condition—Ice glass—has never been observed.* While we know the antithetical vitreous state of so many different crystallised substances, —minerals produced by heat, salts deposited from aqueous solution, neutral bodies of organic origin,—and have great reason to believe that that antithetical condition to crystallisation is universal, we have no knowledge of it in relation to water or ice. My own attention has been awake to the subject, without success, for many years. It would seem to be scarcely within the bounds of possibility that the glassy state of water, if possessing what we term solidity, should not, ere now, either have been observed in nature, or have occurred and been recognised in experimental research."

Mr. Brayley inquires, "Does this apparent deficiency in our knowledge exist because—to use language recently introduced into physical science—the *homologue* of the glassy state of water is not what we ordinarily term solid—because the state of water cooled below 32°, but still liquid, is in fact the state which corresponds to the vitreous condition of other bodies, and to the physical nature of perfect ordinary glass? Is the one simply a case of potential solidity, and the other of the confluent or equivalent state of arrested liquidity?"

In reply to the anticipated objection that the homology sought to be established between liquid water below 32° and glass, is a forced one, and after admitting that, in relation to each other, these are extreme cases, he proceeds to show that intermediate terms of the series are not wanting, some of them being supplied by sulphur and phosphorus, and others, in a remarkable manner, by selenium, various conditions of all three appearing to be homologues, at once, of both the extreme terms here alluded to. Mr. Brayley suggests, finally, "Should this hypothesis be verified, water below 32°,—or rather, perhaps, from the temperature of maximum density downwards through that of freezing,—may have to be regarded as the vitreous condition of matter; and the causes of the peculiar characters of that condition, its effects on the transmission of the vibrations of sound and light, the conchoidal fracture, &c., may have to be discovered by researches on its molecular nature."

In expositions, whether of the progress or the actual condition of any branch of science, the student is perpetually reminded of the lesson which teaches the indissoluble and universal connection of every part of nature with every other part. Subsequently to the enunciation of all the views on the subject of regelation, and the molecular relations of ice and water, of which an account has been given in the preceding columns, this truth has been exemplified in a striking and instructive manner, which may eventually make it requisite to modify all existing conclusions on that subject and its applications to natural phenomena.

In the 'Proceedings of the Royal Society' for June 13 of the present year (1861), vol. xi., pp. 243-247, appears the abstract of an elaborate paper (itself to be published in the 'Philosophical Transactions') on 'Liquid Diffusion applied to Analysis,' by Mr. Thomas (late Professor) Graham, V.P.R.S., Master of the Mint. In this he shows the value of the process of diffusion and of the principle of diffusibility in water, as affording the means of bringing out clearly the distinctive propert what appear, in his judgment, to be two great divisions of che substances. Mr. Graham's former researches on DIFFUSION have b noticed in the article on that subject. As this will be the only op tunity the near completion of our work will allow of giving an ac of his new results, we shall cite so much of his abstract as, in addi to what is required for the subject of the present article, will s for that purpose. The entire subject of diffusion, we may add, il trates in a remarkable manner the importance of that perfect neutra as a chemical agent, which has been shown to characterise water in preceding article on its chemical history.

"The first, or *diffusive*, class of substances are marked by th tendency to crystallise, either alone or in combination with wa When in a state of solution they are held by the solvent with a cer force, so as to affect the volatility of water by their presence. T solution is generally free from viscosity, and is always sapid. Th reactions are energetic, and quickly effected. This is the cla *crystalloids.*"

"The other class, of low diffusibility, may be named *colloids*, as th appear to be typified by animal gelatine. They have little, if a tendency to crystallise, and they affect a vitreous structure. T planes of the crystal, with its hardness and brittleness, are replaced the colloid by rounded outlines with more or less softness and tou ness of texture. Water of crystallisation is represented by water gelatination. Colloids are held in solution by a feeble power, and ha little effect on the volatility of the solvents. The solution of collo has always a certain degree of viscosity, or gumminess, when concentrated. They appear to be insipid, or wholly tasteless, unless when th undergo decomposition upon the palate, and give rise to sapid crys loids. They are united to water with a force of low intens Although chemically inert in the ordinary sense, colloids possess a comparative activity of their own, arising out of their physical propert While the rigidity of the crystalline structure shuts out extern impressions, the softness of the gelatinous colloid partakes of fluidity, and enables the colloid to become a medium for liquid diffusion, lik water itself. The same penetrability appears to take the form of capacity for cementation in such colloids as can exist at a high temperature. Hence a wide sensibility on the part of colloids to extern agents."

"Another eminently characteristic quality of colloids is their mutability. Their existence is a continued metastasis. A colloid may be compared in this respect to water while existing liquid at a temperature below its usual freezing point, or to a supersaturated saline solution. The colloidal is, in fact, a dynamical state of matter; the crystalloidal being the statical condition."

"For the separation of unequally diffusive crystalloids from each other, jar-diffusion was had recourse to. . . . The separation of a crystalloid from a colloid is more properly effected by a combination of diffusion with the [osmotic] action of a septum composed of an insoluble colloidal material. . . . This separating action of the colloidal septum is spoken of [in Mr. Graham's paper] as *dialysis.*"

"*Ice* at or near its melting point appears to be a colloidal substance, and exhibits a resemblance to a firm jelly in elasticity, the tendency to rend and to redintegrate on contact." Regelation, according to this view, is the form in which the property of *redintegration,* belonging to all colloids, is exhibited by ice.*

The truth of the view of the nature of ice, at or near its melting point, thus taken by Mr. Graham, will require to be tested by optical means, by which it must be ascertained that, at those temperatures, it really is not a crystallised body. A further verification may be obtained by determining whether the alleged colloidal ice resists the passage of electricity as crystalline ice is known to do, and what changes the non-conducting power of the latter undergoes, during the reciprocal conversion of the crystalloid into the colloid state, until it becomes the conducting power of liquid water. (Faraday, 'Exp. Res. in Elect.' par. 403.) Should its truth be established, Mr. Graham will probably be admitted to have discovered the key to the explanation of all the conflicting statements and theories respecting the nature of regelation and of the motion of glaciers. Ice, together with many other bodies, and perhaps all, will be both a colloid and a crystalloid. That which Dr. Faraday, in his recent experiments, found to have the flexible adhesion, will prove, in this case, to be the colloidal or vitreous form of that substance (*ice-glass,* in fact; almost identical with Mr. Brayley's homologue of that hitherto hypothetical body, as evinced by facts recorded by Mr. Graham, which will presently be adverted to), while the rigid adhesion will be found to characterise its crystalloidal form; and the circumstances from which he inferred that the former has not in reality the properties of sticking and tenacity—in short, those of a viscous substance, will be found to arise from the constant and rapid passage—the metastasis of Graham—of the colloid into the crystalloid body.

Regelation will consist of the passage, under small changes of pressure and temperature, of crystalloid into colloid ice, and its re-conversion into the former, the "cementation" and "redintegration" of the colloid intervening; and thus Faraday's own interpretation of his experiments and Professor Thomson's will be brought into harmony

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* The Rev. Canon Moseley had previously defined regelation as the "property of passing from a disintegrated into a solid state."

The theories of glacier motion of Forbes, Thomson, and Tyndall (including the explanation of the plasticity of ice by the latter), and the views respecting it of Hopkins and Whewell, may prove to be equally true, or some of them unnecessary. Under the reciprocal changes of pressure and temperature going on in a glacier, it will follow that every part of it must be perpetually changing from a truly viscous or plastic, colloidal, dynamic state, maintained only for a short time, to the rigid, crystalloidal, statical condition of ordinary ice; which, under the same changes will again transiently assume the colloidal form, only to undergo the corresponding change, and so on in a succession which can terminate only with the final liquefaction of the ice, and its separation from the glacier by flowing away in the form of water. All the conditions of viscosity or plasticity, and rigidity, which the phenomena of glaciers and the known properties of ice require to be fulfilled, may thus be capable of explanation agreeably to the laws of nature. But many of Mr. Graham's results are independent of his assumption respecting ice. It is stated by him, as above, that colloidal bodies affect the vitreous structure; and he recognises the vitreous form of silica as the colloidal one. It is now evident, indeed, that what, looking primarily from organic substances, he has termed the colloidal state, is identical, allowing for inherent difference of properties, with that, which, looking primarily from inorganic bodies, has been termed the vitreous or glassy state. Every description of glass must, agreeably to Mr. Graham's inductions, be a colloidal body, and the union of two surfaces of it at all temperatures, while the solid condition is maintained, must be that cementation and redintegration which is physically identical with regelation itself; and thus Mr. Brayley's arguments for the virtual identity with regelation of the process by which two plates of plate-glass become one, which Dr. Faraday's new results appeared to invalidate, will be confirmed; while regelation, as also suggested by him, may be found to be universal, as respects all bodies which can assume the colloid form, Dr. Faraday's experiments indicating its non-extension having been confined to crystalloids. The mutability and continued metastasis of colloids are manifested in the unstable condition of arrested liquidity or potential solidity recognised by Mr. Brayley; and Mr. Graham's comparison of a colloid in that respect "to water while existing liquid at a temperature below its usual freezing point, or to a supersaturated saline solution," is a repetition of Mr. Brayley's view of the molecular constitution of glass already cited. Colloidal ice (if it shall be proved to exist), and unfrozen water below 32°, are evidently degrees of the same condition, and thus Mr. Brayley's suggested homologue of the glassy condition of water is almost equivalent to the former, and if, as seems conformable with known facts, we assume that the colloid state of water cannot begin until it is reduced to the temperature of its greatest density, that homologue will include, almost explicitly, Mr. Graham's colloidal condition of ice. Some nice questions of temperature will, however, have to be settled by experiment; and indeed the subject is now ripe for those quantitative determinations in which the existing discussions of regelation are remarkably deficient, and which must necessarily be of a minute and delicate description.

But here we must conclude on this subject; having merely indicated how wide a field for experimental research, observation in nature, the verification of hypotheses, and mathematical investigation, all relating to ice and water, has probably been opened to science by Mr. Graham's researches on liquid diffusion.

From the preceding view of the obvious characters and actual nature of ice, we proceed to describe some of its properties in relation to heat, and some also of water in its two fluid states. The dilatation of ice by heat was measured in the years 1845 and 1846, at the Imperial Observatory of Pulkowa, by Schumacher and his associates, and the particulars of their experiments were communicated by M. Struve to the Academy of St. Petersburg, in 1848, and were afterwards published in its 'Memoirs.' The measurements had reference to observed temperatures of the block of ice employed, varying from −2°·3 R. to −22° R. (+5°·175 to +17°·5 Fahr.)

After applying the requisite corrections, it resulted from them that the coefficient of expansion of ice is for 1° R. (2°·25 Fahr.) ·00006466; which, according to the Rev. Canon Moseley, F.R.S., "is *nearly* twice as great as the coefficient of dilatation of lead, and *more* than twice as great as that of any other solid." [Heat, col. 637.]

We do not know the modulus of elasticity of ice,* or the pressure under which it disintegrates; but Mr. Moseley has observed that "If it were as elastic as slate and did not resist crushing more than hard brick, a block of it placed with its ends between two immoveable obstacles, would crumble when its temperature was raised one degree of Fahrenheit. It is its great dilatability which gives to ice this tendency to disintegrate, when, not being free to dilate, its temperature is raised, even so slightly as this. Agassiz describes a disintegration of the transparent ice of the blue bands of glaciers when laid bare, which appears to be due to its expansion." 'Bulletin [Bibliothéque] de Genève,' vol. xliv., p. 142; ('Proc. of Roy. Soc.' vol. xi., pp. 171, 172.)

According to the experiments of Melloni on the transmission of radiant heat, ice transmits none (absorbs all) of the calorific rays issuing from copper at 212°, or at 752° Fahr., nearly approaching a red heat; and transmits only 0·5 of those from incandescent platinum, and only 6 per cent. of such rays from the Locatelli lamp. In these cases the heat is absorbed in the internal liquefaction of the ice.

The colour of liquid water varies, according to the thickness of the quantity examined, from a yellowish green of all degrees of intensity through green and blue-green to intense blue, such as that observed in great depths of the sea. Professor Tyndall has introduced into British demonstrative science, if indeed he has not devised, an experiment in which the colour of water is exhibited by passing the light from the voltaic lamp through a long tube of water closed by glass at both ends, and receiving the image on a screen. In this experiment, with no greater thickness than twenty feet, the colour of water is seen to be yellowish green. Ice, probably, has the same range of colour; being, like water, colourless in small masses; it is greenish or bluish in large masses. Pure aqueous vapour is colourless in the greatest thicknesses in which it has been examined.

Many important facts, and inductions from them, relating to the electrical properties of water in all its three states of aggregation, will be found referred to under their respective appellations in the Indexes to Faraday's 'Experimental Researches in Electricity,' and in 'Chemistry and Physics,'—indexes which are enhanced in value by having been constructed by the author of those researches himself.

The process of the solidification of water by depression of temperature is noticed under Freezing, and Freezing and Melting Points. The lowering of its freezing-point by pressure, as discovered by Professor J. Thomson, is stated in the article last cited, and has been referred to in the present article, and also under Ice. The theory and quantitative calculation he originally gave respecting it will be found in the 'Transactions of the Royal Society of Edinburgh,' vol. xv., and the 'Cambridge and Dublin Mathematical Journal' for November 1850. Ice, as a crystalline substance has been described under Hail, Hoar-frost, and Snow. Its specific gravity is stated in the last. Mr. J. Chapman, Professor of Mineralogy in the University of Toronto, in the 'Canadian Journal of Science' for 1861, has questioned the truth of referring the crystallisations of ice to the rhombohedral system. A mode of investigating the process of formation of the stellar and other aggregations of crystals so characteristic of snow, under circumstances more convenient than those of observations which must be made at a temperature below 32° Fahr., has been pointed out by Mr. Joseph Spencer, and adopted by Mr. Glashier. It consists in observing the crystallisation of camphor, in which similar aggregates are produced; and has been described in papers read before the Greenwich Natural History Club, in the year 1856, and issued by the British Meteorological Society. The compressibility and Elasticity of water have both been treated of under the latter head.

The phenomena of the conversion of liquid into gaseous water or aqueous vapour, and its properties in that condition, have been stated in the articles Boiling of Liquids; Ebullition; Evaporation; Steam; Vapour; and Vapour Opalescent; those of its reconversion, or condensation, into liquid water and ice, under several heads above referred to, and also in the articles Dew and Rain. The evaporation of ice has been noticed under Snow.

The absorptive power for heat of aqueous vapour has recently been examined by Professor Tyndall, in his researches on the absorption and radiation of heat by gases and vapours, ('Phil. Trans.' 1861); in which he found that hydrogen, the two gases which are the essential constituents of the atmosphere, and atmospheric air itself, absorb respectively about 0·3 per cent. of the calorific rays emanating from a copper surface coated with lamp-black, heated by boiling water. "On a fair November day," he adds, "the aqueous vapour in the atmosphere produced fifteen times the absorption of the true air of the atmosphere. It is on rays emanating from a source of comparatively low temperature that this great absorptive energy is exerted; hence the aqueous vapour of the atmosphere must act powerfully in intercepting terrestrial radiation; its changes in quantity would produce corresponding change of climate. Subsequent researches must decide whether this *vera causa* is competent to account for the climatal changes which geologic researches reveal." 'Proc. of Royal Soc.' vol. xi., pp. 101, 102.

Under Evaporation, Hygrometry, and Vapour, an account has been given of Dr. Dalton's researches and views respecting the production and tension of aqueous vapour and its relations to the atmosphere, which for many years have been almost universally accepted and relied upon. Meteorologists, accordingly, have been accustomed to separate the pressure of the aqueous vapour from the whole barometric pressure of the atmosphere, and thence to infer the pressure of the permanently elastic portion, or as it has been called, the *gaseous pressure*, or the *pressure of the dry air*. Colonel Sykes, in a paper read before the Royal Society some years since, and Lieut.-Col. Strachey in a recent communication 'On the Distribution of Aqueous Vapour in the Upper Parts of the Atmosphere,' have questioned both the truth of Dalton's hypothesis and the correctness of the application. A mathematical argument, showing the incompatibility of the hypothesis of a separate vapour atmosphere with the facts, will be found in a paper by the late astronomer Bessel, translated in Taylor's 'Scientific Memoirs,' vol. ii. A more generally appreciable form has been given to this by Lieut.-Col. Strachey, who also has compared the results calculated from Dalton's hypothesis with the facts of the distribution of vapour in the atmosphere, as observed by Dr. Joseph D. Hooker, the late Mr. Welsh, Colonel Sykes, and himself. From the entire investigation he concludes that "The subtraction of the observed tension of vapour from the total barometrical pressure, in the hope of obtaining the simple gaseous pressure, must consequently be denounced as an absurdity; and the barometrical pressure, thus corrected, as it is called, has no true meaning whatever." ('Proc. of Royal Soc.' vol. xi., pp. 182-189.)

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* The expression "modulus of elasticity," we believe, has not been explained in any preceding article. It is thus defined by Dr. Thomas Young, Sec. B. L., by whom it was introduced. "The modulus of the elasticity of any substance is a column of the same substance, capable of producing a pressure on its base which is to the weight, causing a certain degree of compression, as the length of the substance is to the diminution of its length." This definition is given in Dr. Young's 'Mathematical Elements of Natural Philosophy,' appended to his celebrated 'Lectures,' Lond., 1807, vol. ii., p. 46. It occurs in Section ix, treating 'Of the equilibrium and strength of elastic substances.' These elements are not inserted in Professor Kelland's edition of that work; but the section is reprinted in the late Dr. Peacock's collection of the 'Miscellaneous Works' of Dr. Young, vol. ii., p. 129. The application of the expression is explained and illustrated in Lectures xiii. and xxxi.

On the other hand, the application of Dove's method for obtaining the gaseous pressure, deduced from Dalton's hypothesis, in Major-General Sabine's paper on the 'Meteorology of Bombay,' published in the 'Report of the British Association' for 1844, appears to have been successful in bringing out true results, which also verify the law assumed. It would appear that there is something important on the subject yet to be explained; probably in respect of the relation of the observed phenomena which Dalton expressed by the hypothesis of gaseous substances being vacua to each other, to their aggregate pressure when mingled, and the manner in which that is made up of their separate pressures, if such they have.

WATER (*Medical Uses of*). Several of the uses of water having been already stated, either under the article BATHING, or that of FOOD in ARTS AND SCIENCES, or WATER, in NAT. HIST. DIV., it is intended to treat here of some of the applications of water.

Snow-Water has been accused of causing goître; but this charge seems unfounded; and the occurrence of that complaint is due to the calcareous salts which the snow-water in its descent from the mountains dissolves in large quantities.

Such is the great purity of some springs, that they have been reckoned *mineral* waters, and resorted to as such. The chief of these is Malvern, the specific gravity of which is only 1·0002, and which contains a smaller proportion of foreign ingredients than any other water. The water now supplied to the City of Glasgow, from Loch Katrine, is nearly equally pure, a point of great importance to the health of the inhabitants, and to the numerous manufactories of that city. Water artificially purified by Dr. Clark's process, is supplied to Woolwich. Some of the springs of Matlock are likewise very pure. Those of them which are *thermal* have their powers increased by the higher temperature; but their beneficial effects, like those of Malvern, and Holywell in Flintshire, are mainly owing to their extreme purity; which shows how conducive to health pure water is, compared with that which is impure or contaminated. Many springs have their waters largely impregnated with carbonic acid gas. These are sparkling and pleasant to the taste, and when fresh-drawn produce some slight exhilaration.

Water charged with much free carbonic acid should never be conveyed through leaden pipes, but through those of zinc or block-tin.

Well-water is generally obtained from a greater depth than spring-water. It is also generally hard, or is apt to become so if kept in a reservoir lined with bricks, unless they be coated with an insoluble cement. The water from old wells is more pure than from recent ones, the soluble particles having been all gradually washed away. The pump and well waters in and about London, and chalky districts in general, are mostly hard. (Prout, 'On Stomach and Renal Diseases,' p. 210, 4th edit.) Not so that of the artesian wells, which is of unusual softness. This renders water from these wells proper as a beverage for persons with a tendency to certain forms of calculous complaints, to whom hard waters are most hurtful. The causes of hardness in water and of the injurious influence of it on the health of many persons, is scarcely sufficiently understood. Filtration only removes mechanical impurities, and even long boiling only precipitates certain of them, while in some instances it renders the water harder. For the analysis of water and an estimate of its mechanical impurities, see WATER (*Chemistry*); and for the means of determining its hardness, see SOAP-TEST.

Distilled Water.—For many chemical, pharmaceutical, and even dietetical purposes, water must be of greater purity than it is generally found. For this end it is directed to be distilled, in which process never more than two-thirds of the water put into the still should be allowed to pass over.

Toast-Water.—This is water boiled and poured on toasted bread, which in some degree lessens the vapid taste. An agreeable and beneficial degree of sapidity may be communicated to water which has been long boiled, by adding, previous to drinking it, a little of the common soda-water, which is merely carbonic acid gas diffused through the water under strong pressure.

Mineral Waters are generally characterised by possessing some principle different from what is found in common water, or some of the ordinary principles in unusual proportion, yet among these are reckoned certain springs which have no claim to repute beyond what is due to their extreme purity, such as Malvern and Holywell; or to having a higher temperature throughout the year, than the mean of the latitude where they are situated. These last are classed among the *thermal* springs, which are properly divided into two sections: the *mineralised hot* springs and the *unmineralised*, among which are some only tepid, such as Matlock, where some springs are 66°, the lowest of the class in Britain, and others cold, presenting this peculiarity, that the tepid springs arise from fifteen to thirty yards above the level of the river Derwent, whilst those which arise either above or below this range are cold.

For practical purposes mineral-waters may be classed under four heads, each susceptible of secondary heads, according as they are hot or cold, or have other peculiarities, namely; saline, alkaline, chalybeate, and sulphureous. It will not be possible to mention more than a few of the most important of each.

Saline aperient springs: of these some are hot, others cold. The chief are Carlsbad, Marienbad, Egra, Kissingen, Wiesbaden, Baden-Baden, Seidlitz, and Saidschutz, with Pullna, in Germany; Cheltenham, Leamington, and Harrowgate in England; Dunblane, Pitcaithly, and others in Scotland.

Alkaline waters, owing their properties to different saline principles, are found at Carlsbad, Marienbad, Kissingen, Pullna, Saidschutz, Ems, Töplitz, and Wiesbaden, in Germany; Vichy and Mont d'Or, in France; Harrowgate, Scarborough, and other Yorkshire springs, Cheltenham, Leamington, Bath, and elsewhere, in England.

Chalybeate waters: with these acidulous waters are often reckoned, as the iron is often associated with much free carbonic acid gas. Some of the chief are Spa, Pyrmont, Schwalbach, Marienbad, Aix-la-Chapelle, and Seltzer in Germany; Tonbridge, Harrowgate, and Brighton, in England; and Peterhead, in Scotland.

Sulphureous waters: Aix-la-Chapelle, Barèges, and other Pyrenean springs, are hot; Harrowgate, Askern, and others in Yorkshire, cold, Moffat and Strathpeffer, in Scotland, are also cold.

Ioduretted and other waters. Many springs have of late been found to contain a notable quantity of iodine or bromine, others contain both: Creuznach, in Germany, contains both, but most iodine; Llandrindod and Park Wells (near Builth), in Radnorshire, the springs issuing from the lias at Leamington, Gloucester, Tewkesbury, and Cheltenham, contain iodine; bromine, but not iodine, exists in small quantity, in the saline aperient waters near London, such as Epsom, also in the springs from the coal-formation of Ashby-de-la-Zouch, Newcastle-on-Tyne, and Kingswood, and Bonnington near Edinburgh: Woodhall, near Ashby-de-la-Zouch, contains most iodine of any British springs yet investigated.

Organic matters, termed *Baregine, glairine, zoogene, &c.*, have been found in many springs. Of these an account may be found in Dr. Lankester's 'Askern, and its Mineral Springs,' p. 103.

The waters of Selters (commonly called Seltzer) is exported to the amount of above a million and a half bottles. So also those of many other mineral springs; but they all experience some deterioration by time. To lessen this, artificial imitations are made [AERATED WATERS]. These are often very valuable, but always inferior in efficacy to the waters drank at the springs. They are without the *Juvantia*, the change of air, scene, relaxation from business, and more regular hours and appropriate diet, insisted on at the chief watering places; to say nothing of the external use of many of the waters as baths, when resort is had to the fountain head.

(See Osann, *Darstellung der bekannten Heilquellen Europas*; Gairdner, *On Mineral and Thermal Springs*; Vatter, *Theoretisch-praktisches Handbuch der Heilquellenlehre*; *Dictionnaire des Eaux Minerales*, par MM. Durand-Fardel, Le Bret, Lefort, et François; Paris, 1860. *Report of Commission on Health of Towns.*)

WATER-COLOUR PAINTING (in Italian, *Acquarella*; French, *Aquarelle*; German, *Wasser-Farben*). Among the ancients the colours used in painting were usually rendered fluid by means of water; the names given to the different kinds of painting being derived from the vehicle or medium mixed with the water in order to bind the colours. TEMPERA, or distemper, in which glue or some other gelatinous binder is employed; FRESCO, in which the colours are laid on a moist ground of gesso, or plaster-of-Paris; MINIATURE, are all water-colour painting: their history, and an account of the several processes, will be found under their respective titles: see also the general article PAINTING. In ENCAUSTIC PAINTING, as the name implies, heat was employed, the binding material being wax, or wax and resin; but some even of the methods of encaustic, or at least of wax-painting, as practised by the ancients, were really water-colour, the wax or resin being rendered miscible by the addition of an alkali (nitrate of soda, or nitrate of potash). Oil-painting was not practised, or only practised in an imperfect form, before the 15th century, when Van Eyck introduced the use of oil and varnish, or a vehicle composed by boiling linseed, poppy, and nut oils with certain resinous mixtures. This vehicle was, however, found to be so much better adapted than any then in use for working, and so much more effective and durable, as to be generally adopted by artists as soon as it became known; and the various methods of water-colour painting were neglected, and fell into disuse, except for mural paintings, for which fresco was still employed, and theatrical paintings and miniatures, which were commonly painted in tempera. [PAINTING; VAN EYCK, in BIOG. DIV.]

Water-colour painting, as the term is now understood—that is, painting on paper with colours diluted with water—is a process of comparatively recent introduction. It is true that the Italian, Dutch and Flemish painters of the best period often executed their cartoons and finished sketches with water-colours, as may be seen in the cartoons of Raffaelle and of Mantegna at Hampton Court, which are painted on paper with opaque water-colours (or tempera), and in some of the sketches and drawings executed in transparent water-colours by leading Dutch and Flemish painters, of which examples are exhibited in the King's Library at the British Museum: these, however, were not completed pictures, but only the drawings from which fresco or oil-paintings, or tapestry hangings, were to be executed. The art of water-colour painting, in which the completed work is itself executed, with all the skill and care of the artist, in water-colours on paper, is a product of this country. It appears to have gradually grown out of the methods employed by miniature painters, and the earlier examples were rather a kind of tempera than what would now be called water-colour painting, the colours being all rendered opaque by the admixture of white. Many of the early works of Paul Sandby [Sandby, Paul, in Biog. Div.], who perhaps has the fairest claim to be regarded as the founder of the English school of water-colour painting, are wholly executed in solid opaque colour. The new method, from which was directly derived the present process of water-colours, grew into vogue in the latter part of the last century, and was at first known as "stained drawing," a term by which pictures of this kind are described in the catalogues of the early exhibitions of the Royal Academy. The entire drawing was first carefully made out in light and shadow by means of washes of Indian ink, or of a gray or what was termed a neutral tint, and over this the respective local colours were passed in thin washes of transparent colours—much of the effect being due to the neutral tint appearing through and modifying the harshness of the superposed colours. The sharp-markings, minuter details, &c., were put in with a reed-pen either immediately before or subsequently to the laying on of the local colours. The older works in this manner have generally a cold, gray, feeble appearance, but sometimes very pleasing atmospheric effects were obtained; and in the hands of Cozens, and still more of Turner, Girtin, and Prout, whose earlier drawings were all commenced with a monotint, pictures of great power and even grandeur were produced.

The improved method, and that which, in principle at least, is still practised, consisted in abandoning the preparatory neutral ground tint, and painting-in every object in the first instance in its proper local colour, leaving it to subsequent shades and tints, either laid in thin washes of transparent colour, or with a kind of *hatching* stroke (the distinctive "touch" of the artist), to modify the crudity of the first painting, and to impart the character and aspect which every part should assume from its place in the picture and the atmospheric influences under which it is seen. This method originated, there can be little doubt, in the adoption by the younger landscape painters, Turner, Girtin, and their compeers, of the practice of making out-of-doors sketches and studies of scenery in colours, for which purpose the old method of employing a preparatory monotint would be found too tedious, and for representing evanescent atmospheric phenomena impracticable; while the striking effects that were produced in sketching by painting-in the local colours at once would soon lead to the adoption of a like method for more finished works. Yet even Turner and Prout continued to lay-in the larger masses of shadow with a monotint, long after they employed local colour in the first instance in the lights and middle-tints. When once the new method came to be generally adopted, the progress of the art was very rapid; water-colour painting acquired a remarkable degree of popularity, and its professors became very numerous. In 1805 the most distinguished practitioners of this branch of art formed themselves into a "Society of Painters in Water-Colours," which has ever since continued to hold an annual exhibition of the works of its members at their rooms in Pall Mall East. In 1832 the younger practitioners, feeling that they were unable to bring their works fairly before the public, established another society under the title of "The New Society of Painters in Water Colours," and they have in like manner their annual exhibition. But both exhibitions are exclusively confined to the productions of the members. At the Manchester Art-Treasures Exhibition of 1857, a very instructive collection of paintings in water-colours was brought together with a view to illustrate the growth of the art, and it may be anticipated that a much more complete collection of a similar kind will be shown at the International Exhibition of 1862. The want of a permanent national collection of paintings in this essentially British branch of art has however long been felt, and though it has not yet been supplied, the nucleus of such a collection has, mainly by the spirit and munificence of private individuals, been at length formed. [South Kensington Museum.]

The practice of water-colour painting as at present pursued in this country differs so much according to the habits of individual artists, and so little guidance could be given in a brief description of any particular method, that it will be best to confine ourselves to a few general remarks. The paper employed is usually of a hard substance, and more or less granulated according to the size and character of the picture, and still more the manner of the artist: some using paper with only a fine and others with an exceedingly coarse grain or *tooth*. Some again prefer an absorbent paper, or paper of a peculiar tint, and others produce a peculiar texture by rubbing, sponging, or other manipulative process: some of the most remarkable effects in their pictures (as in the case of Turner and Copley Fielding for instance) being to a great extent due to some such procedure. The pigments employed are of the ordinary kind, prepared in cakes by the admixture of a little gum, or "moist" by the addition of honey or some other saccharine material. The colours, as we have said, are painted-in of their proper local hue, and subsequently modified till the objects acquire the intended appearance. This was by the older painters usually effected with transparent colours only; but Turner, Harding, and others began, at first cautiously, and then with more freedom, to mix white with their colours, and this has been carried so far that now opaque (or *body*) colours often form, as of old, the substance of the water-colour paintings of some of our most admired artists. Another innovation is that of using gum, or some other vehicle of a like quality (water-glass has been tried), to give *depth* to the shadows. These are however objected to by many as not legitimate materials for the water-colour painter; but the majority of painters consider that it is lawful to use any means by which they can best convey the impression they desire to produce; and, supposing that equal truth and permanency as well as brilliancy can be so obtained, there can be little doubt that they are right. It must, however, be admitted that in many of the more elaborate recent pictures, something of the exquisite freshness and transparency of the earlier water-colour paintings has been lost in the attempt to reach the force and depth of oil.

WATER, COMPRESSIBILITY OF. [Elasticity, col. 773.]

WATER AND WATERCOURSES. The right of conducting water through one piece of land for the use of another is an incorporeal hereditament of the class of easements, and was known in the Roman law by the name of the *servitus aquæ ductus.* The right of taking water out of the well or pond belonging to another person is an incorporeal hereditament of the class of profits called in the Roman law the *servitus aquæ haustus.* These rights, in our law, must be either derived from a grant or established by prescription. [Prescription.]

It is the law of England that water flowing in a stream is originally *publici juris*, that is to say, a thing the property of which belongs to no individual, but the use to all. The legal presumption is that the proprietor of each bank of a stream is the proprietor of one-half of the land covered by the stream, but there is no property in the water. Every proprietor has an equal right to use the water which flows in the stream, and consequently no one can have the right to use the water to the prejudice of any other without his consent. No proprietor can either diminish the quantity of water which would otherwise descend upon the proprietors below, nor throw back the water upon the proprietors above, so as to overflow or injure their lands. For the same reason, no proprietor has a right to use the water of a stream so as to injure its quality to the detriment of other proprietors.

The only modes in which a right to the use of running water, in a manner inconsistent with the common law rights of others can be established, are either proof of an actual grant or licence from the persons whose rights are affected, or proof of an uninterrupted enjoyment of such a privilege for such a period as the law considers sufficient to constitute a right by prescription. The period of twenty years had been generally fixed upon by the courts of law and equity for this purpose, and the same period has been adopted in the Prescription Act (2 & 3 Will. IV., c. 71, s. 2). [Prescription.] But if water has not been appropriated, it seems that the person who first appropriates and renders it useful acquires a right, and for a violation of such right an action may be maintained on an enjoyment of less than twenty years.

The privilege of a watercourse is not confined to private individuals. It may be vested in a corporation, or may be claimed by the inhabitants of a township or parish. If land with a run of water upon it be sold, the water *primâ facie* passes with the land; but it is laid down by Coke that if a person grants *aquam suam*, the soil will not pass, but only a right of fishing in that water; for the proper words in that case to pass the soil would be, so many acres of land *aquâ coopertas*: whereas the word *stagnum*, or pool, will pass both water and land. (1 'Inst.,' 4, b.) The exclusive right to a flow of water once acquired can only pass by grant as an incorporeal hereditament, and a licence, by parol or otherwise, to use or take the water at any place, may be revoked even without an express power of revocation being reserved, unless works have been constructed and expenses incurred upon the faith of it.

When the owners of property have, by long enjoyment, acquired special rights to the use of water in its natural state, as it was accustomed to flow, and not merely a use, which is common to all the king's subjects, an action may be maintained for a disturbance of the enjoyment; but where the injury, if any, is to all the king's subjects, the only remedy is by indictment. The mere obstruction of water which has been accustomed to flow through a person's lands does not in itself afford a ground of action. The plaintiff in such an action must be enabled to show, either that some benefit arose to him from the water going through his lands, of which he has been deprived, or at least that some deterioration was occasioned to the premises by the subtraction of the water; but where the proprietor of the lands can prove that he is injured by the diversion of the water, it is no answer to his action to show that the defendant was the first person who appropriated the water to his own use, unless he has had twenty years' undisturbed enjoyment of it in its altered course. If the injury occasioned by the diversion or obstruction of water is of a permanent nature and injurious to the reversion, an action may be brought by the reversioner, as well as by the tenant in possession, each for his respective loss.

The diversion of watercourses or injury to their banks so as to cause inundation are nuisances against which a court of equity will protect parties by injunction; and if there be a question as to the right to the flow of water, an issue will be directed to try it. Although a court of equity will not in terms decree the banks of rivers, watercourses, or navigable canals to be repaired, the effect of such an order may be obtained by an order that parties shall not be at liberty to use them while out of repair, or against their impeding the use of them by the obstructions consequent upon a state of disrepair. An injunction may also be obtained against conducting the water from one man's tenement upon that of another to his injury by drains or otherwise, in a manner in which it has not been accustomed to flow. And it may be laid down generally, that, with respect to water and watercourses, the aid of a court of equity may be obtained for the purpose either of restraining injury or of quieting possession.

WATERFALLS. In the article VALLEYS we have arranged a general view of the main features of the earth's surface, and a series of inferences touching the forces whereby the diversified forms of hills and valleys have been occasioned. But these forms, though on a large scale they appear permanent, because the great modifying agencies which produced them have passed away, are really undergoing continual change from causes in daily operation. The most solid stone is wasted by the feeble but unceasing power of decomposition possessed by the atmosphere. Rain washes away the disintegrations occasioned by varying temperature and chemical processes; the hills lose and the valleys gain, and the balance of decay and renewal of land is only finally adjusted on the shores and in the basin of the sea. Among the phenomena which show this mutability of the supposed solid land with most distinctness, are interruptions to the general uniformity of the inclinations of valleys and the even slopes of hills: for these changes of slope are points of variation of the intensity of the agencies excited by the slope. These interruptions of uniformity are all referrible to the unequal power of resistance which rocks of different hardness, or dissimilar position, or unequal thickness, or unlike modes of association present to external agencies. Thus have been formed round the high limestone hills of the northern counties a series of rocky terraces, not less regular than the escarpments made by military art; and thus the oolitic ranges of the Cotswold show horizontal mounds of sand and cliffs of stone above the broad plains of lias clays and red marls which margin the Severn and the Avon. On these grand features of the earth's surface the action of the atmosphere (including chemical and mechanical operations) produces only slight modifications; but when the terraced slopes in their flexures round the hills turn into the valleys, a new agency is brought to work upon them. Rivulets, however small in quantity, and torrents, even such as are of only temporary energy, exert a positive influence in wasting and transporting away earthy materials; and these effects rise to a maximum wherever, from any of the causes already alluded to, the surface of the earth presents successive points of less and greater power to resist the action of running water. Wherever, in a valley whose slope is considerable, the rocky masses successively crossed by the stream are of very unequal hardness, as, for example, when solid limestone is found resting on soft shale or feebly indurated sandstone, a more than ordinarily rapid current is occasioned over the lower beds of the limestone into the upper beds of the shale. This difference of slope in the running water is of a nature to increase continually to a certain point, depending on the relative firmness and thickness of the hard and soft rocks, the inclination of the valley, the magnitude of the stream, and other less important particulars. Thus rapids and cataracts are formed; and where the conditions combine in the most favourable degree waterfalls, to use that term in a more specific sense, are produced.

The character of these varies according to the disposition of the yielding and resisting portions of the rocks. Wherever stratification is absent, as in granite, or concealed, as in some metamorphic slates, the main features of the waterfall are determined by the direction of the natural joints in the stone. Hence the picturesque character of the falls of the Bruar (Highlands), Lodore (Cumberland), and the Rheiddiol (North Wales). In some cases these natural joints yield in parallel lines, and give a deep narrow passage to the water. Scale Force, in Cumberland, is an example. But the most interesting, if not the most picturesque, class of waterfalls, is occasioned by the stratified rocks; and the most curious of them are observed where hard limestones or gritstones rest upon yielding shales or soft clays. By the continual action of the stream, the shales, kept constantly damp, crumble and fall away even at considerable heights and distances from the points where they are touched by the water. Thus, a hollow space is formed beneath the limestone which crowns the precipice; and this proceeds so far as to reach at last some of the natural joints which divide the rock. Then the limestone falls down, the waterfall recedes, and the process of removal and destruction is renewed. Thus, on the sides of the hills, in the limestone dales of the northern counties of England, the waterfalls are daily receding up the streams, and thus are the Falls of Niagara forced continually farther up the river. The process is by no means slow. Beneath Hardrow Force, in Yorkshire (a fall of 99 feet), the effect since the general valley of the Yore was excavated by other forces has been to produce a sinuous glen within vertical walls of rock, at the foot of which yet lie great heaps of materials, which the feeble stream that formed the glen has not powerful enough to remove. For an account of the natural process by which the Falls of Niagara have been displaced, and are still going change, the volumes of Sir C. Lyell ('Principles of Geology 'Travels in North America;' the former of which are instructive all points connected with the operations of running water) may consulted. Exactly such effects as are here attributed to running streams happen on the sea-coasts where rocks of a particular nature occur under analogous circumstances.

The physics of waterfalls have received but little attention, though it might have been anticipated that they must involve considerations of an interesting nature, and of some philosophical importance; for them we have the principal cases in nature of the mechanical agitation and division of water, resulting chiefly from its own inertia, gravity and momentum. In the greatest waterfall in Europe, for example, Vöring Fos, near the Hardanger Fiord, in Western Norway, we have very large body of water, and a clear fall of 900 feet. It descends into a narrow bare chasm, the sides of which are very nearly perpendicular. "The spray dashes up from below with such force, that another waterfall, which descends on the opposite side of the chasm is actually stopped by it and dispersed before it can reach the bottom (H. F. Tozer, 'Vacation Tourists in 1860.')

The late Captain Basil Hall, in his 'Travels in North America thus describes the involution of air in the Horse-shoe Fall of Niagara and its subsequent disengagement. "This enormous cataract, in descent, like every other cascade, carries along with it a quantity air, which it forces far below the surface of the water, an experiment which any one may try on a small scale by pouring water into tumbler from a height. The quantity of air thus carried down by vast a river as Niagara must be great, and the depth to which it driven in all probability considerable. It may also be much condensed by the pressure; and it will rise with proportionate violence both the outside of the cascade, and within the sheet or curtain which forms the cataract." He mentions also the blast of wind which rises accordingly from the pool on the outside of the sheet. To the explosion, as it may be termed, of the bubbles, thus constituting this enormous and perpetually renewed accumulation of bursting froth, we must ascribe the greater part of the sounds which combine to produce the roar of the Niagara falls. In doing this we apply to the subject the observations of Professor Tyndall, on the sound of breakers and the roar of the ocean. ('Vacation Tourists in 1860,' p. 307, note.) The impact of water against water, he has shown, is a comparatively subordinate source of sound; though in this case, from the enormous masses of water concerned, and the momentum which those of the river acquire from the height from which they descend, the sounds proper to the impact must be very considerable. The sonorousness of the roar, also, agrees with this ascription of it, principally, to the violent impact of air against air, the air impinged upon being that of the free atmosphere, by which the sound is communicated to the ear. The explosions of the bubbles must take place, in many instances, with enormous force, owing to the resistance presented by the immense cohesive power of films of water, and occasion corresponding loudness of the sounds, which, however, in coalescence and rapid succession are heard as an interminable roar.

To these, no doubt, enormous bubbles of condensed air, rushing upwards to the surface of the pool, and expanding as they rise, we must also probably attribute the production of the sharp-pointed cones of water which are continually projected upwards from the pool on the outside of the fall, sometimes to the height of a hundred and ten or twenty feet. They are further described by Captain Hall (who, however, expresses no opinion as to their origin), as resembling some comets in form, their point, or apex, which is always turned upward, being quite sharp, and not larger, he estimates, "than a man's fingers and thumb, brought as nearly to a point as possible. The conical tails which stream from these watery meteors may vary from one or two yards to ten or twelve, and are spread out on all sides in a very curious manner." The actual production of these cones, and their emergence from the surface of the pool, which must be their beginning above water, if the origin here ascribed to them be the true one, are concealed by the clouds of spray in which the bottom of the falling sheet is constantly hidden from the view. Out of this they are at all times seen darting up.

This cloud or mist of spray is itself an interesting phenomenon, characteristic more especially of great falls, like those of Niagara, uniting depth of fall and quantity of water. It arises from the bottom, where the impact of the descending upon the still or merely flowing water takes place; and it involves several physical considerations which seem to have escaped notice. As produced by the Niagara falls, its extent and visibility from a distance have often been described. The lower part of the great fall, according to Captain B. Hall, is always concealed by this rolling cloud of spray, which waves backwards and forwards, and rises at times to the height of many hundred feet above the falls. Isaac Weld describes it as consisting of thick volumes of whitish mist, having much the appearance of smoke rising from heaps of burning weeds; such smoke, it may be added, itself consisting principally of steam condensed into globules of water, or steam-cloud. The same traveller relates that this "cloud formed from the spray" of the Niagara falls was seen by him and his party on Lake Ontario, at the distance of fifty-four miles, as "a small white cloud in the horizon," which remained steadily fixed in the same spot, its shape, as observed by a telescope, "varied every instant, owing to the continued rising of the mist from the cataract beneath." But it is only seen at such a distance, he adds, when the "air is very clear and there is a fine blue sky." Weld also describes the now well-known appearance of coloured bows in the spray, similar to rainbows, and for which it will be convenient in this article to use that appellation.

Notwithstanding the production of these rainbows, proving the mist to consist of separate drops of water, in the condition, in fact, of small rain, it has frequently been described as vapour, and identified in nature with fog and the clouds of the sky,[*] although rainbows do not occur in them, and although we have no reason to believe that the conversion of water into vapour can ever take place by mechanical action, however violent and continued. Were this possible, indeed, it could not but take place at these falls, where the water is perpetually exposed to the consequences of greater mechanical force than under any other circumstances whatever, either in nature or art; where indeed all the circumstances are most favourable to such conversion, were it physically possible.

We have seen in the example of the Vöring Fos, how enormous is the force with which the spray into which the descending is divided by the momentum with which it falls upon the still water, and partly, no doubt by the resilient elasticity of the latter, is driven upwards. Such spray, but greatly varying in magnitude, number, and approximation of particles, and therefore in their aggregate effect and appearance, may be produced under conditions in which water impinges with great force upon water, or upon solid bodies, or solid bodies upon it; also as in storm-spray, by the action of the wind on the surface of the sea, by which, as by the perpetual action of waterfalls, persistent mist is frequently occasioned. Further, it is produced to a sufficient extent for the appearance of rainbows, when the waves of the sea, at their summits, curl and break into foam under the force of a breeze. But the spray-mist of great waterfalls is in all probability occasioned, in the greatest degree, and as consisting of the most minute particles, by the violent bursting of the multitudinous air-bubbles already described, forming the froth or foam of the falls, by which the films of water inclosing the air are rent into minute dust, as it were, of water, incalculable in the number of particles in a given space, and capable of suspension in the air, like the globules of which the clouds of the sky themselves consist. [Clouds.]

These particles, however, differ greatly from those of the clouds, and the connection of their history with the subjects of the smallness of the particles into which water is thus mechanically divisible, and the true nature of the clouds, and of the globules or particles composing them, is in several respects instructive. The spray of waterfalls and of the crests of waves consists of globules or particles of water, resulting, exclusively, from its mechanical division; but the production of perfect rainbows in it evinces that it is identical, within certain limits, in respect of the magnitude of the particles, their distance from each other, and their distribution in a given space, not with true cloud, but with the minute rain in which the rainbow of the sky occurs under ordinary circumstances. We have, therefore, in the production of that meteor, a kind of measure of the magnitude, constitution, and distribution of the particles, which, in all these cases, it is demonstrable must be geometrically solid.

We have, in several articles, already recorded our belief that the globules constituting the clouds are not hollow, and our disbelief of the existence of what has been termed 'vesicular vapour,' that is, of vesicles of water (whether containing vapour or not), resulting from the condensation of invisible vapour or water in its pure gaseous condition. Sir J. F. W. Herschel ('Meteorology,' par. 92,) after describing the production of mist or fog [Mist] by the precipitation of moisture from the atmosphere, offers the following important observation on the subject in question.

"It is a favourite dogma with many meteorologists, that the particles so precipitated assume the form, not of drops, but of hollow spheres or bubbles. De Saussure states that he has seen such floating before his eyes in clouds and fogs on the Alps; and the dusty appearance of the vapour floating over a cup of coffee in the sunshine is adduced in proof. The strongest argument in their favour, however (for there is great room for optical illusion in such matters), is that adduced by Kratzenstein, that the sun striking on a fog or cloud [†] produces no rainbow, which it ought to do were the water collected in spherical *drops.* This argument does not admit of a ready answer; but the difficulty, on the other hand, of conceiving any possible mode in which such bubbles can be formed, disposes us to believe that the extreme minuteness of the globules may perhaps be found to afford one, their diameters being probably of an order comparable with the breadths of the luminiferous undulations."[*]

In the steam-cloud issuing from the boiler of a locomotive engine, whether immediately above the funnel, when blowing off, or at a distance from it, or in the puffs of steam given off during the course of the engine, no rainbow is ever visible, as the present writer can testify from observation: they appear to be physically identical with the clouds of the sky. With this agrees another point, the production in all these cases of opalescent vapour [Vapour, Opalescent; Weather], which also is always caused in the clouds of nature; intervening, as a middle term, in the conversion of invisible vapour into cloud, and in the resolution of cloud into invisible vapour. Its occurrence in both processes may be observed in and about the clouds at almost all times during the presence of the sun, or just before or after it; but less frequently, and only under favourable circumstances, in moonlight. The solar radiation, and the capacity of the air for more vapour on and above the upper surfaces of clouds, often render the intervention of opalescent vapour invisible in that situation, but it may always be seen in the reverse process, in the vapour-plane or vapour-zone [Vapour-Plane] at the base of masses of clouds, especially of cumuli. But the production of opalescent vapour does not occur with the spray of waterfalls or waves. The reason seems obvious. The clouds of the atmosphere and of the steam-engine consist of globules so minute that very slight local changes of temperature will effect their resolution, and so near to each other that the amount of opalescent vapour produced by every one, individually, coalesces into an aggregate mass for all, so that, though only momentary for each globule, it is persistent for the mass, and therefore becomes visible. But the particles of the spray are, comparatively, so large, that much greater differences of temperature are required for their conversion into invisible vapour, and also so distant, comparatively, from each other, that the local momentary opalescence ceases, before, by the coalescence of that produced at many points, it can become visible.

We may safely conclude, therefore, it would appear, from all these facts and arguments, and in corroboration of opinions generally but not universally held, that the clouds are really composed of excessively minute globules of liquid water, not hollow, and not consisting in any respect of *vapour* (though necessarily intermingled with it), which, having resulted from the condensation of volumes of continuous vapour, or of vapour no otherwise discontinuous than as occasioned by the uniformly interspersed particles of the air, are formed at insensible distances from each other; and that these at length (under circumstances not altogether understood, and whether related primarily to heat or to electricity is also uncertain) coalesce into much larger globules, or drops, exceeding in diameter the breadths of the luminiferous undulations, and therefore capable, like the drops of waterfall- and wave-spray, of exhibiting the rainbow.

Minute globules or particles of water, it is now evident, exist of several orders of magnitude, each order having characteristic properties, whether of its own, or arising from the mutual distance of the particles and their consequent number in a given space, or from the mingling with them of pure transparent aqueous vapour, or air, or both.

The application to waterfalls of Professor Tyndall's observations on the sound of agitated water, was founded merely upon his note in the 'Vacation Tourists,' cited above, the writer of the above remarks on the physics of the subject not having seen the paper in the 'Philosophical Magazine' referred to in that note, until after they were in type. Professor Tyndall, after alluding in that paper ('Phenomena of a Water-Jet') to the roar of the ocean as being caused by the bursting of bubbles, himself applies his inferences to waterfalls in the following manner:—"It is the same as regards waterfalls. Were Niagara continuous and without lateral vibration, it would be as silent as a cataract of ice. It is possible, I believe, to get behind the descending water at one place [this is readily practicable, and frequently done]; and if the attention of travellers were directed to the subject, the mass might perhaps be *seen through.* For in all probability it also has its 'contracted sections,' after passing which it is broken into detached masses, which, plunging successively upon the air-bladders formed by their precursors, suddenly liberate their contents and thus create the thunder of the waterfall."

Professor Magnus, of Berlin, it appears, was the first to account for the production of bubbles when water is poured into a glass,—the same physical phenomenon as their production by waterfalls. It is briefly thus, as he proved by experiment: a concavity is formed by the falling water at the point where it strikes the water below; this closes in as soon as the least motion has been imparted to the surface, and the air within it is carried downwards. It will readily be seen how illustrative this explanation is of a part of Capt. B. Hall's account of the air-bubbles at the Niagara falls, and of the applications of it above; but no part of the air, it must be inferred from the experiments of Professors Magnus and Tyndall, is carried down by adhesion to the water.

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[*] Sir C. Lyell, for example, in his 'Travels in North America,' first identifies the spray-cloud of Niagara falls with the clouds of the atmosphere, and then with the undoubted steam-cloud rising from Etna (and other volcanoes), which he also identifies with the clouds, regarding both phenomena as elucidating their nature. But while the steam-clouds of volcanoes are indubitably of the same nature with the clouds of the atmosphere, the spray-cloud of Niagara, as shown above, is different, notwithstanding its appearance.

[† The coloured bow similar to that produced by rain observed in mists lying upon low grounds, as mentioned in the article Rainbow, is evidently caused by the drops of water resulting from the aggregation of the aqueous particles constituting the mist, by the same process as the production of rain from clouds.]

[*] This is one of the very few cases in which it has been possible to consider the sensible magnitudes of the particles of ponderable matter as proportioned to the measurable attributes of the ether, or to treat them as commensurate. Another case has been pointed out by Dr. Faraday, who has shown that seven and a half leaves of gold-leaf might be placed in the space occupied by a single undulation of the red ray of light, and five in one of the violet ray; so that a single leaf of beaten gold occupies in average thickness no more than from one-eighth to one-fifth part of a wave of light. ('Proc. of Roy. Inst.,' vol. ii., p. 310; 'Phil Trans.,' 1857, p. 147.)

In another part of his paper, Professor Tyndall, illustrating experimentally the subject of the contracted vein [Hydrodynamics, col. 774], describes the resolution of the vein or stream of water, after passing the contracted section, into detached masses; and observes, "Following the jet downwards, we find that these masses become more and more attenuated; and were the height sufficient, they would finally appear as a kind of water-dust, an example of which on a large scale is furnished by the *Staub-bach*, near Lauterbrunnen, in Switzerland. Travellers usually attribute the breaking up of the Staub-bach to atmospheric resistance, but the latter has comparatively little to do in the matter; were the surrounding space a vacuum, the same would be exhibited." This indicates an additional and very effective cause of the production of waterfall spray, and is probably applicable to the phenomena of the Vöring Fos, noticed above, which appear not to be accurately understood. (See 'Phil. Mag.' Series 4, vol i. p. 1, and p. 105.)

WATER-GLASS PAINTING, a method of painting in which the vehicle, or binder of the colours, is a soluble alkaline silicate. This process, which has been in use for some years in Germany for mural-painting, and in which Kaulbach, among others, has painted all his later wall-pictures, appears to have been invented, or greatly improved, by Dr. Johann N. Von Fuchs, who termed it *Stereochromy*, and published a pamphlet explanatory of the process and pointing out its advantages. This has been translated for private circulation by direction of the Prince Consort (chiefly with a view to the consideration of the applicability of the process to the paintings in the New Palace at Westminster), under the title of 'The Manufacture, Properties, and Applications of Water-Glass (soluble alkaline silicate), including a Process of Stereochromic Painting.' Mr. D. Maclise, R.A., who was engaged on the preparatory labours connected with painting in fresco a large picture, 'The Meeting of Wellington and Blucher,' in one of the two spaces (45 feet in length) in the Royal Gallery of the House of Lords, and who had been greatly impressed with the failure, as regards permanency, of the recently-painted frescoes, was led by a perusal of this pamphlet to determine on submitting the water-glass process to a searching investigation. He accordingly made various experiments, and, not succeeding to his satisfaction, proceeded to Germany to make himself acquainted with the method as actually practised there, and to examine the works executed. The result was his conviction of its suitability. He has since executed various trial pictures, and he is now painting his great picture with water-glass. Mr. J. R. Herbert, R.A., who is engaged in painting the Peers' Robing-Room, also, having, "after repeated experiments, modified it according to his own views," expresses himself entirely satisfied with it. As its working capabilities have so far satisfied the practical artist, and the finished examples appear to have withstood successfully not only the effect of time,—as yet too brief to be conclusive,—but also the various tests hitherto applied, the process would seem to merit very attentive consideration. The frescoes painted within the last few years, not only in this country, but in Germany, where so much more attention has been given to them and artists are so thoroughly familiar with all the working details, have for the most become deteriorated to a very marked extent; and it will be an immense gain if the water-glass process proves to be a really permanent, as it would seem to be in other respects an efficient, substitute. It will be no doubt interesting to give a brief general statement of the process; for further particulars we refer to the 'Twelfth Report of the Commissioners on the Fine Arts' (1861), in an appendix to which Mr. Maclise has given a very full account of his experience and ample details of the modes of working.

The Water-Glass is composed of powdered quartz (silica) boiled in purified potass or soda, but, according to Dr. Pettenkofer, the chief authority on the subject, the potass solution is to be preferred. It is prepared by chemists of different degrees of strength, according as it is to be employed for laying-on the colours or for fixing. The pigments are the same as those used in fresco-painting, but zinc-white is the only white that can be relied on. The ground is an intonaco, formed of river-sand and Portland cement, precisely as for Fresco, but somewhat more absorbent. Kaulbach has the ground prepared with a granulated surface, insisting that "it should feel to the touch like a coarse rasp;" but this does not appear to be necessary. A smooth ground, if carefully prepared, takes the colours with equal facility; and, in fact, the degree of roughness or smoothness may be regulated at the pleasure and according to the manner of the painter. After the intonaco has been well dried, and the cement hardened, the superficial sand is to be swept off, and the surface to be moistened with a saturated solution of carbonate of ammonia (Mr. Maclise, we believe, employs lime-water), when it is ready for painting on.

The painting itself may be executed in two ways. In the first, the water-glass in a diluted form is mixed with the colours, and used as a vehicle in working. But Mr. Maclise found that it was hardly possible to work with such a vehicle with sufficient facility, "because of its stiffening the brush, and, as it were, petrifying the contents of the palette before the painting could be accomplished even by the most rapid execution." The solution may, of course, be diluted so as to admit of the painting being executed with much greater facility; but this can only be done at the expense of the fixing qualities of the fluid.

The other method—that employed by Kaulbach and his assistants and adopted by Mr. Maclise—consists in simply using distilled water as the vehicle, and finishing the parts as they advance; and on the following day, when the finished work is quite dry, applying to it a solution of water-glass, formed of "two parts water and one of the concentrated liquor imported from Berlin, and this solution having been twice applied, the painting is now perfectly fixed." (Maclise.) Mr. Maclise applies the water-glass "freely with a large flat water-colour brush." The Berlin artists use a syringe of peculiar construction; and Mr. Maclise finds great advantage in "shedding, by means of a syringe, a spray of coloured water over any portion of the wall-painting," and thus producing "very easy and pleasing changes in hues" where it may be deemed necessary. The principal conditions of success appear to Mr. Maclise to be that the picture should be thinly painted, water be freely used, and the ground be carefully prepared and very absorbent.

In appearance water-glass painting bears a close affinity to fresco. It is flat, free from glossiness, and the colours appear opaque; but the surface may be rendered glossy by using a concentrated solution of the water-glass as a varnish. As it is for mural painting, however, that the water-glass method seems especially fitted, the flat unshining surface is an advantage. In comparison with fresco, its superiority seems to consist in the colours remaining quite unaltered whilst working and when dry; in the process allowing the picture to be retouched and carried out to any degree of finish not only during its progress but after the "fixing;" and, finally, that it promises to be permanent. On this last and most important point we may remark that whilst Kaulbach's great frescoes have become seriously deteriorated, his large water-glass paintings remain quite uninjured; and in Munich some stereochrome pictures are said to have existed for twenty years without exhibiting any symptoms of decay, whilst the frescoes are all more or less damaged.

WATER, HOLY (in French, *Eau bénite*, or blessed water; but in Italian, *Aqua santa*, as in English), is water blessed by the priest, which is used in many ceremonies of the Roman Catholic church, as in the offices of baptism and burial, and in various parts of the mass or ordinary service. There is commonly a font of holy water in the porch of Roman Catholic churches, into which the congregation as they enter the church dip their fingers, and then make the sign of the cross upon their foreheads. The holy water is mixed with salt; and this is said to have been first done by Pope Alexander I., in the beginning of the 2nd century. Some make Pope Alexander to have been the inventor of holy water altogether. Protestant writers have been accustomed to trace the holy water of the Romish church to the pontifical lustrations of the pagan Greeks and Romans; but both the pagan and the Christian practice may perhaps be more correctly referred to the natural feeling which points out water as the symbol of purification. In the ancient churches, in the middle of the Atrium, or square plot of ground between the porch and the church, was commonly a fountain or cistern of water, in which the people washed their hands and faces before they entered. Holy water is also used in the Greek church, but without salt. The mixture of the salt and water is interpreted by some Roman Catholic divines as typifying what is called the hypostatic union of the nature of Christ, the salt being the emblem of his divinity, the water of his humanity.

WATER-MACHINES. [Turbines; Water-Wheels.]

WATER-MEADOWS. [Irrigation.]

WATER-MILLS. [Water-Wheels.]

WATER-PARTING, in physical geography and geology, the term recently substituted for that of Watershed, taken as the equivalent of the German *Wasserscheide*, in its primary and original signification, that of the line of separation between the contiguous basins of two rivers. [Rivers; Watershed.]

WATER-PIPES. In addition to what has been said on the subject of the flow of water in pipes under Pipe and Water Supply, it may be desirable here to mention a few practical matters connected with their manufacture and use.

The wooden pipes formerly employed were made from elm trees, and of about 14 or 15 feet in length, the diameter rarely exceeding 9 inches; the interior was bored out by an auger; the joints were of the kind known as the spigot and faucit, in which one end of the tree was tapered for a length of about 9 inches, and the end of the pipe destined to receive that taper was *rimered out* to fit it. These pipes have now been entirely abandoned, on account of their not being able to resist the pressures they are exposed to in modern works, and of the bad flavour they communicate to the water.

The cast-iron pipes are laid with socket joints run with lead; the depth of the joint being proportioned to the diameter of the pipes, but even in the largest it does not exceed 6 or 8 inches. A great effort has lately been made to introduce turned and bored joints for water distribution; but the disturbance of the ground, and the unequal dilatation of the pipes, have hitherto prevented the successful application of that system. It is customary to cast the smaller pipes, that is to say those of from 2 to 3 inches in diameter, in lengths of 6 feet each; and the pipes of greater dimensions in 9 feet lengths. The thickness varies between $\frac{5}{16}$ths of an inch for a 2-inch pipe, $\frac{7}{16}$ths of an inch for a 6-inch, $\frac{5}{8}$ths of an inch for a 12-inch, and $1\frac{3}{8}$ for a 44-inch pipe; the latter dimension is the largest hitherto adopted, and the only instance recorded of the use of such pipes is in the great Rivington Pike supply to Liverpool. Of late years an attempt has been made to introduce the wrought-iron pipes of large diameter, coated externally with asphalte, on Chameroy's patent; but in practice so many inconveniences have been found to be attached to them, that the cast-iron pipes are now almost exclusively used in the ground, when the water is under pressure.

Glazed earthenware pipes are frequently used to convey water, when it is not under pressure; but the difficulty of keeping the joints water-tight has hitherto prevented this material from being much used for water supply. From the nature of the earth used in the manufacture of stoneware pipes, their length cannot exceed 3 feet; and consequently the number and expense of the joints would be a fatal objection to any such application.

As to lead pipes, the joints are made by soldering the two ends of the pipes together, the ends *meeting butt*, as workmen say. Up to a diameter of 2 or 3 inches lead pipes can be drawn; beyond that dimension they are formed by rolling sheet-lead over a mandril, and then soldering the longitudinal lap. Joints so made are hardly able to resist the effect of the enormous pressures used in modern water-works, for at the present day the ordinary cast-iron pipes are tested to a pressure of 300 lbs. on the square inch; and in the case of the great Liverpool pipes the pressure was even carried to 600 lbs. per inch. As a general rule lead pipes are made $\frac{1}{4}$ of an inch in thickness. The junction of service-pipes upon cast-iron mains is effected by fixing a brass ferrule to the latter, and soldering the service-pipe to the ferrule; and it would appear that the intervention of the ferrule is sufficient to prevent the galvanic action between the iron and the lead, which would otherwise take place. All the small taps, valves, &c., upon service-pipes are made of brass; but the plugs, sluices, and valves, upon the mains are usually made of cast-iron. Zinc is rarely used for the purposes of water supply, and it is never used for the service-pipes; wrought-iron pipes themselves are not so much used for this purpose as lead, on account of the greater ductility of the latter metal.

WATER-POWER and WATER-PRESSURE ENGINES. The weight and the impetus of a stream of water are frequently employed in mechanics as a source of motive power for the machinery used in industrial operations, in the form of the various kinds of water-wheels; and of late years the law by which water and other similar (practically) incompressible fluids transmit pressure in every direction, and tend to assume a constant level in any reversed syphon, has been made to serve the purposes of mechanics by furnishing the power exerted by the so-called hydraulic cranes and the water-pressure engines. The term *water-power*, therefore, simply refers to the force developed by the water in its natural fluid state; and it acts either by its weight, its impact, or by its power of transmitting an effort exercised upon any part of its circumference. In an overshot wheel the water acts almost exclusively by its weight, which is applied on one side of an unbalanced wheel; in an undershot wheel the water may often exercise power by reason of the velocity with which it is animated when it strikes the floats; in a reaction wheel the power is produced by the escape of the water from a pipe reacting upon the air surrounding the apparatus; and in the hydraulic cranes, the power is obtained by forcing water into a raised cistern, from whence it is able to act, as workmen say "with a head," upon the underside of pistons bearing loaded surfaces. Virtually it is the weight of the water which produces the useful effect in all these cases; but the interferences with its action are so numerous as to justify the popular distinctions above referred to.

The various descriptions of WATER-WHEELS are described under that head; at present it is intended only to notice the water-pressure engines used in mining operations, and the hydraulic cranes; because they constitute applications of water-power of so peculiar a nature, as not to justify their being included under the more generally known classification of water-wheels or engines. The mode of their application is also different from that of the ordinary forms of water-engines; the latter being usually employed for the purpose of driving machinery or mill work, the former for raising water, or for hoisting weights only.

The *water-pressure engines* are constructed upon the principle of collecting, in a tube of a certain height, a quantity of water, and in allowing that water to escape when it has produced the desired effect. This is accomplished by placing the underside of a piston, moving in a vertical cylinder, in communication with a column of water, and in cutting off that communication when the piston has arrived at the head of its stroke. The pressure of the column of water acts, in fact, to raise the piston, to which the pump rods are attached; and the alternate downward motion is effected by the weight of the pump rods themselves, in the same manner that the pump rods of the Cornish engines work: the bottom of the cylinder is placed in communication also with the outflow, so as to allow the water to escape after it has done its work. The passages for the water are opened and closed by a series of tappets and equilibrium valves of a peculiar description, in order to avoid any abrupt hydraulic jar from the change in the conditions of flow in the descending main; these details are, however, of too complicated a nature to allow of their being represented here, but they may be studied in the notice of the water-pressure engine at Huelgoat in the 'Annales des Mines,' or in Burat's 'Géologie appliquée.' In the best engines of this description the useful effect obtained is usually about 0·45 of the power exerted; though it has been stated that in the pumps lately executed at Freyberg, as much as 0·75 of the real power has been used. Mountainous districts are the most favourable for the establishment of the water-pressure engines; for it is only in them that the necessary conditions for their economical working occur naturally. These are, that a sufficiently copious supply of water should exist at a considerable height above the seat of the piston; and that a free discharge for both the water which has served as the motive power and for the water raised should exist. The Huelgoat engine is placed at a distance of 360 feet from the surface, and it raises the water from a mine 754 feet below the level of the cylinders; the diameter of the piston is 3 feet $4\frac{3}{8}$ inches, its height 9 feet, and the length of the stroke 7 feet $6\frac{1}{2}$ inches; it makes, when in full work, $5\frac{1}{2}$ strokes in a minute, and raises through the total height of 754 feet, in one lift, 396 gallons per minute; there are two cylinders, but the galleries are not sufficiently advanced to keep them constantly at work: the descending and outflow pipes are 15 inches in diameter, the pump barrel is 18 inches in diameter, and the ascending pipe is $10\frac{5}{8}$ in diameter. M. Reichenbach has executed for the salt springs of southern Bavaria a great number of these water pressure engines; and it may be desirable to add that the one at Illsang is set in motion by a fall of water 328 feet in height, and that it raises, in one lift, not less than 1364 cubic feet of water.

The hydraulic or water-pressure cranes were invented by Sir W. Armstrong, and applied by him to the quays of Newcastle about the year 1846, in the first instance; but subsequently, their use has become general in other towns, wherein water is to be obtained under considerable pressure. In these engines the water is admitted to act upon one side of a piston working in a tight cylinder, and bearing a piston-rod, upon the end of which is fastened a chain passing over two fixed pulleys, under the pivot of the crane, and over a moveable one on the head of the piston itself, in order to increase the distance traversed by the load, at the expense of the power. The stroke of the cylinders is usually long, and by thus passing the chain over the three pulleys, the load is raised through a height equal to three times the stroke; but the load is correspondingly reduced in proportion to the effort exerted on the piston. There are valves placed at the bottom of the cylinder to close the access of the water to the piston, and to open the escape passages; and when the latter are opened the water escapes, and the weight of the piston, and of the machinery attached, brings the piston back to its original position. Relief-valves are placed near the slide-valves, which give access or egress to the water, to guard against any sudden shocks from changes of direction in the movement of the water which might be likely to produce a hydraulic jar. The water-pressure cranes used at Newcastle had cylinders 12 feet long by 1 foot in diameter, and they worked under a head of water equal to 240 feet.

The principle of the hydraulic press is, in fact, the same as the one involved in the water-pressure engine and the hydraulic crane. It consists in the faculty by which water transmits in all directions a power exercised upon any portion of its surface; the difference in the mechanical arrangement being simply that in the hydraulic press additional force is applied by means of levers and pumps, whereas in the pressure-engines the statical pressure of the source of supply is alone brought into operation. [HYDRAULIC PRESS; HYDRODYNAMICS.]

WATERPROOFING. Textile fabrics, whatever be their character, are pervious to water from two causes: namely, the existence of minute spaces between the individual fibres of the yarn, whether of silk, cotton, wool, or flax; and the rectangular meshes consequent on the process of weaving. To close up these minute channels, as likewise the pores of leather, so as to impart a waterproof quality to the material, has been the object of a large number of patents, as well as of recipes which have not been patented. Mr. Hellewell took out one of the earliest of these patents, for a solution which should render cotton and other fabrics waterproof. According to this plan, for a quantity of woven material equal to 1000 lb. weight, there are used 120 lb. of rock alum, 80 lb. of common whiting, and 200 gallons of water. This mixture is intended, by the chemical action of its ingredients, to yield a solution of alumine, with which the cloth is saturated. After the saturation the cloth is passed quickly through a vessel containing a solution, at a temperature of 100° Fahr., of yellow soap in water, the proportions being 3 lb. of soap and 30 gallons of water to 50 lb. of cloth. This latter process is for the purpose of fixing the alumine in the interstices of the cloth, and enabling it to resist the action of water. The cloth is finally washed, to free it from any impurities. Mr. Hall patented a method of waterproofing cloth by immersion. He describes two kinds of solution employed for this purpose. 1st, two ounces of pulverised alum are dissolved in a pint of distilled water; one ounce of dry white-lead is rubbed down in another pint of water; and the two solutions being mixed and allowed to settle, the supernatant liquor constitutes the required agent. 2nd, one ounce of dry white-lead is rubbed down in half a pint of water; one ounce of pounded alum is dissolved in another half-pint of water; and these two solutions, together with two fluid drachms of acetic acid, are mixed together, and allowed to settle. When the cloth has been immersed in the supernatant liquor resulting from either of the above solutions, it is passed through a solution of quicklime, and a third time through a solution of boiled Irish moss, which acts as a mucilage. One more example will suffice:—Boil half an ounce of Russian isinglass in a pound of soft water till dissolved; dissolve an ounce of alum in two pounds of water; dissolve a quarter of an ounce of white soap in a pound of water; strain these solutions separately through linen, and then mix them all together. Heat this liquid till it simmers, and apply it with a brush to the wrong side of the cloth, on a flat table. When dry, the cloth is brushed lightly with water. The intention of this process is to render the cloth impervious to water, but not to air.

The *surface*-application of a species of waterproof varnish has been the subject of many patents. Messrs. Mills and Fairman introduced a composition, formed of 100 lb. of linseed oil, 40 lb. of pipeclay, and a small quantity of burnt umber, white-lead, pounded pumice-stone, and one or two other substances. These ingredients were melted together and ground to a smooth paint-like state, and then applied to the surface of the fabric with large knives, the cloth being stretched over wooden frames. When one surface was thus coated and dried, the other was similarly treated. This was not intended as a waterproof composition for ordinary clothing, but rather for tarpauling, awnings, coach top-covers, boat-cloaks, and other coarse materials. Mr. Newberry's patent is for a mode of applying waterproof composition in such a way as to leave one side of the woven fabric free from its influence, thereby presenting to the eye a texture nearly resembling that of ordinary cloth. The method consists in saturating the cloth with the waterproof composition, and exposing one surface only; in such a way, that the atmosphere, or artificial heat, may harden the composition on that surface into a dry membranous film; while the other side, after being kept moist during the drying of the first, is cleansed from the composition by means of spirit of turpentine. Mr. Newberry describes three modes of effecting this object. In the first mode the cloth or woven fabric is stretched over a frame, and after being saturated with the composition, is allowed to float on a layer of oil till the upper surface is dry; after which the lower surface is cleansed from the composition. In the second mode the cloth is stretched double, or in two plies, over a frame, saturated with the composition, and then left to dry on the exterior surfaces, the contact-surfaces remaining moist until the time of removal. In the third mode recourse is had to a roller, on which the cloth is coiled, and a flat table of slate, stone, varnished wood, or other substance non-absorbent to the composition. The table is coated with a layer of the composition, and the cloth, being uncoiled and laid down upon it, is pressed and rolled till every part becomes wetted by the composition beneath. In this way the upper surface may be cleansed while the lower is in contact with the table, and the latter is then exposed to a drying process.

The application of a layer of cement, gum, or varnish between two other substances, with a view to render the inner one impervious to water, has been practised under many different modifications, including that which is known by the name of the inventor, Macintosh. Mr. Weise of Bermondsey devised a peculiar kind of fabric, which seems to bélong to the class now under consideration. This fabric was to be used either as a material for hats and bonnets, in lieu of the usual felted beaver, or as a cloth for other garments. The materials consisted of beaver-fur, musk-fur, hare's wool, Spanish wool, flax, down, and waste silk, any or all of which were to be combined, according to the kind of fabric required. The materials were carded, roved, and spun into yarn, in the manner of cotton; and this yarn was soaked in a solution of caoutchouc, or Indian rubber, to render the interstices between its fibres waterproof. The yarn was then woven into a textile fabric; and in order to render the meshes impervious to water, the cloth was drawn over a heated cylinder, whereby the resinous composition was so far melted as to flow into them. The last part of the process was to raise a pile or nap on the surface by means of teazles or brushes.

In Mr. Macintosh's patent of 1824, the use of a cement between two layers of cloth was introduced. The cement, or thick elastic varnish, was made by dissolving caoutchouc in a small quantity of coal-oil, the proportions of the ingredients varying according to their quality. This invention led to the remarkable series of processes for waterproofing noticed under CAOUTCHOUC MANUFACTURE.

The attempts to render *leather* waterproof depend in general on the filling up of the small pores which have previously admitted the tannin; the substance imbibed being such as will repel or resist water. Many such methods have been proposed at different times, of which it will be enough to mention a few. Melt over a slow fire a quart of boiled linseed oil, a pound of mutton suet, three-quarters of a pound of yellow bees'-wax, and half a pound of common resin, or smaller quantities in the like relative proportions; and with this mixture saturate the leather of new boots or shoes, while the latter is slightly warm. Another method is to melt two ounces of yellow bees'-wax, two ounces of Burgundy pitch, and two ounces of turpentine, in a pint of linseed oil, and with this mixture to saturate the warmed leather. The 'Journal of the American Institute' gives the two following:—1. Boil together for half an hour one quart of linseed oil, two ounces resin, and half an ounce of white vitriol, to which add four ounces spirits of turpentine and two ounces of white oak sawdust, and apply this mixture to the leather by means of a brush. 2. Apply a coat of tallow to the leather; and after this has dried, coat it again with a mixture of one part of copaiba balsam with two of naphtha. Another mixture for this purpose consists of six ounces of caoutchouc boiled for two hours in two quarts of linseed or neats'-foot oil. Lastly, a mode has been much recommended of applying a hot mixture of two parts tallow and one part resin, with which the leather may be completely saturated, the resin imparting an antiseptic quality to the tallow.

One of Mr. Sievier's contrivances is for rendering leather at once elastic and waterproof. A thin sheet of leather is cemented to a thin sheet of solid caoutchouc by a caoutchouc solution, and kept under pressure for five or six days. The compound fabric thus formed is nearly inelastic, because the leather has temporarily suspended the elastic power of the caoutchouc; but by the application of a temperature about equal to 180° Fahr., the caoutchouc partially collapses, and the leather assumes a corrugated surface, similar to Morocco leather. The leather, rendered thus elastic and waterproof, is then manufactured into boots and shoes or other articles.

WATERSHED. It has been observed, in the article RIVERS, that the margin of a river-basin generally lies contiguous to the basin of another river, and therefore constituting the boundary-line of two basins, the waters descend on both sides into their respective basins; and hence the whole line of these margins, it has been stated, is called a *watershed*—properly, the *water-parting*.

It might be supposed that this is simply a matter of nomenclature relating to a single and definite elementary phenomenon of physical geography. But this is far from being the case. The term we are explaining, originally introduced in the sense just described, has been extended, apparently, to every physical locality in which tributary streams having their confluence in a river-basin issue from, or descend on the face of, sloping land, without reference to those on the other side of a ridge, or on the counter-slope; and this extensive application often obscures, in geographical description, the original sense of the term. Of these various applications, examples will be found in the citations which follow.

The Rev. C. G. Nicolay, in the 'Manual of Geographical Science' (vol. i., Terminology, pp. 422-3), enters into the following elaborate and critical discussion of the manner in which this term is to be understood:—"The tendency of water to seek its level makes the position and quantity, as well as character, of the waters of the globe, dependent on its contour; every conical projection, every ridge, in short, every elevation of what sort soever it may be, becomes a watershed; and that knowledge of the height, slope, and direction of the various watersheds of the earth's surface the first step to its general contour. The word watershed, in geographical definition, implies the line by which any waters are divided from each other, and the watershed of any country is no doubt such a line; but as every slope sheds water, and many rivers have their rise on slopes below the main watershed, some further division of the word—some classification of the districts to which it is applicable—appears highly desirable. As this does not seem to have been ever attempted, the following is offered as a suggestion.

"That there is a line in every country which may be termed its principal watershed, will not be disputed; every country has some one district, usually in the direction of its greatest length, more elevated than another, from the sides of which the waters collected from snows, dew, rain, and springs pour down, until they are received into the basin of some inland water, or at last into the sea; this may, therefore, be properly termed its primary watershed; but as the mountains of the world cannot be satisfactorily considered, except in their relative connection, the highest ranges extending through the greatest length of the continental masses, the term primary watershed should be confined to these; beyond them others of less considerable elevation are found, the slopes of which are presented towards the primary watershed and form with it deep hollows, into which their united waters are poured, while from the opposite slope the waters collected descend in a different direction. These may, not inaptly, be termed secondary watersheds, as paying the tribute of part of their waters to the primary, and forming the inferior limit to the principal river basins; while others rising beyond may be called tertiary. It will be observed that this classification affords not only a systematic division of the elevated land, but also of the waters of the globe, as appertaining to any of its parts; rivers having their rise in the primary watersheds may also receive a similar designation, as may their basins; others may be termed secondary or tertiary, according to their position and the watersheds to which they belong."

In Dr. Beke's records of travel and geographical works, the term "water-parting" is substituted for "watershed," for which change he assigns the following reason:—"The line of division and separation between the contiguous basins of two rivers, called by the ancients *divortio aquarum*, the parting (or flowing in opposite directions) of the waters, is in German called *die Wasserscheide*, which means literally the same. English geographers, following the example of geologists, have adopted the expression 'watershed,' which is evidently a corruption of the German *Wasserscheide*, and was probably first introduced among us by miners from Germany. The term is, however, objectionable; because, to the mere English scholar, it appears to be a native compound of the words 'water' and 'shed,' as if meaning that the water is *shed* in opposite directions, and hence leads to the belief that the side of the basin of a river, rather than the division between the adjoining basins of two rivers, is intended. In fact, the expression has of late years been frequently used in that sense. The substitution of the term 'water-parting' renders the idea intended to be conveyed intelligible to all, and exactly expresses the Latin *divortio aquarum*, and the German *Wasserscheide*." ('Sources of the Nile,' p. 3, note.)

Dr. Beke's remarks are amply justified, it will be seen, by the previous discussion of Mr. Nicolay, and also in the following statement on the philosophy of the subject as one of the configuration of the globe, by Sir J. F. W. Herschel, who, it will be observed, while adopting by previous implication the term watershed, in its primary signification, evidently connects it also with the meaning of the English word *to shed*. "Possessed of a knowledge of the heights of stations above the sea, we may connect all stations at the same altitude by level lines, the lowest of which will be the outline of the sea-coast; and the rest will mark out the successive coast-lines which would take place were the sea to rise by regular and equal accessions of level over the whole world, till the highest mountains were submerged. The bottoms of valleys and the ridge-lines of hills are determined by their property of intersecting all these level lines at right angles, and being, subject to that condition, the shortest and longest, that is to say, the steepest and the most gently sloping courses respectively, which can be pursued from the summit to the sea. The former constitute 'the water-courses' of a country; the latter its lines of 'watershed,' by which it is divided into distinct basins of drainage." ('Outlines of Astronomy,' par. 289.)

Again, Captain H. Strachey, and his brother Lieut.-Col. R. Strachey, to whose contributions to scientific geography we have so often referred, designate the northern and southern faces, or slopes of the great table-land of Thibet [PLAINS] as the Turkish, and Himalayan or Indian 'watersheds' respectively; meaning the entire inclination, between the table-land and the low plains to the north and south, occupied by successive ranges of mountains, down and through which the great rivers maintaining a course along the summit of the table-land, and receiving the drainage of its corrugations, flow into those plains, namely, the plains of Hindostan on the one hand, and those of Turkistan or Yarkend on the other. ('Phil. Trans.', 1859, pp. 776, 777.) Here we have another modification of the sense in which the term we are discussing is to be understood, referring to a slope, not as giving rise to streams, or separating them, but as merely giving them passage. In the signification of *Wasserscheide*, the water-parting, the highest part of the table-land itself is the watershed. But Lieut-Col. Strachey defines the meaning in which he uses the term by referring to "the crest of the Indian watershed," which is merely the summit of the slope.

Finally, an eminent geographer and geologist, Professor H. D. Rogers, in his account of the parallel roads of Lochaber, [VALLEYS, col. 544] states that each of them coincides "in level with some watershed, or notch in the hills leading out from its glen into some other glen;" implying only by watershed an opening, by which water escapes to a lower level, and merely adopting one of the senses of the word shed.

We find, therefore, that at present the expression watershed is employed, by the first authorities, to denote any portion of inclined land on which water appears or descends from a higher to a lower level.

The spirit of Dr. Beke's remarks on the subject is applicable to other scientific terms which have been derived from the German language, and especially to those adopted from the phraseology of miners. Both geography and geology were cultivated as sciences in Germany before they had become such in England; and mining in the former country was already a systematic art with a copious terminology. Some of the principal founders also of modern geology in England had been students in the celebrated school of Freiberg under Werner, which became an additional cause for the introduction of German terms into scientific nomenclature. This, indeed, was inevitable, and might have been unexceptionable, but an erroneous procedure took place, of which we have an example in the term which is the subject of the present article. Barbarous imitations of German terms and phrases were made, instead of expressing their meaning in sound English words, or constructing compound terms derived from the perennial sources of the Greek or Latin languages. This was done even by men who were fully competent to take these preferable alternatives; thus, the late Rev. Dr. W. D. Conybeare, afterwards Dean of Llandaff, who was an ornament of the University of Oxford, and a geologist of great merit, substituted, about fifty years ago, the term *strike*, now universally employed by English geologists, for the German word *streich*, to denote the direction of stratified rocks, at right angles to their line of dip, as referred to the cardinal points. An unreasonable horror of technicality and abstruseness appears to have prevailed among the gifted men to whom we have alluded, who, in their anxiety to avoid burdening the new sciences they were fostering with unfamiliar expressions, left them almost without an appropriate vocabulary, the want of which, especially in geology, has still to be supplied, in many instances, by awkward and sometimes tedious periphrasis.

It is worth the remark that the propriety of Dr. Beke's substitution seems to be tacitly admitted by other geographers; for in the index to the 'Manual of Geographical Science,' published with the second volume, the passages above cited from Mr. Nicolay, explaining the applications of "watershed," are referred to by the words, "water-parting, meaning of term," although that term does not occur in them. This may be taken as an indication that it may not be too late to establish "water-parting" for the primary sense in which "watershed" has been received; but we think that the latter may be accepted also, confined, however, to the secondary meanings to which, as we have seen, it has been extended, and more particularly to those involving the obvious meaning of the English words of which it consists.

The importance to the inhabitants of a country of the geographical configuration or phenomenon described by the term water-parting, and the influence which a particular example of it may exert in the production of national ideas, is curiously illustrated by the Rev. A. P. Stanley's interpretation, adopted and extended by Dr. Beke, of the story told to the historian Herodotus, in Egypt, by the treasurer of Minerva's Treasury at Sais. This was, that there were two mountains, named Crophi and Mophi, rising into sharp peaks, situated between the city of Syene in Thebais, and Elephantine; and that the sources of the Nile issued from between those mountains, half of the water flowing over Egypt and to the north, and the other half over Ethiopia and to the south. Herodotus observes that by the deep unfathomable sources described to him in this story were meant the violent eddies of the cataracts; and Mr. Stanley argues, that to the ancient inhabitants of Lower Egypt, the sight or the report of such a convulsion as the rapids make "in the face of their calm and majestic river must have seemed the very commencement of its existence, the struggling into life of what afterwards becomes so mild and beneficent; and that if they heard of a river Nile further south, it was but natural for them to think it could not be their own river. The granite range of Syene formed their Alps—the water-parting of their world. If a stream existed on the opposite side, they imagined that it flowed in a contrary direction into the ocean of the south." ('Sources of the Nile,' p. 43; Stanley's 'Sinai and Palestine,' p. xliii.)

WATERSPOUT, a meteorological phenomenon of the same class probably as the whirlwinds which raise pillars of sand in the deserts of Africa: such whirlwinds, in fact, become waterspouts when they reach the sea; and when waterspouts reach the shore they in some cases become or produce whirlwinds. But there is much reason to believe that the name has been properly applied to several very different phenomena.

The following is a general description of the production of a waterspout at sea:—

Below a thick cloud the sea appears to be greatly disturbed within a circular area, whose diameter varies from 100 to 120 yards, the waves tending rapidly towards the centre of the agitated mass, where there is formed a vast body of water or aqueous vapour: from hence there rises, with a spiral movement, towards the cloud, a column of a conical form, resembling a trumpet. Vertically above this ascending column there is formed in the cloud, but in an inverted position, a corresponding cone, whose lower extremity (the apex of the cone) gradually approaches the summit of the ascending column; and at length both are united, the diameter at the place of junction being only two or three feet. The waterspout is said to be accompanied, during its formation, by a rumbling noise; and, when complete, it assumes a magnificent appearance. The whole column, which extends from the sea to the clouds, is of a light colour near its axis, but dark along the sides, which gives it the appearance of being hollow.

The spout appears to move with the wind, though even when no wind is felt it sometimes varies its position, tending successively in different directions. It frequently happens that the upper and lower parts of a column move with different velocities, and then, after the whole has taken an inclined position, the parts separate from one another, often with a loud report. Previously to the rupture of the column, the dark parts seem to be drawn upwards irregularly, leaving only a slender tube in connection with the water below. The whole of the vapour is at length absorbed in the air, or it descends into the sea in a heavy shower of rain. The duration of the phenomenon is various: some spouts disappear almost as soon as they are formed, and others have been known to continue nearly an hour: occasionally they form themselves, continue for a short time, vanish, and again appear, and so on several times successively.

Waterspouts are occasionally seen above land (of which some remarkable examples will be described in the sequel), and consequently there is then no ascending column of water or vapour to meet that which descends from the clouds. In Dr. (Sir David) Brewster's 'Journal of Science' (No. 5) there is an account of one which was seen in France: it is stated to have appeared like a conical mass of vapour, and to have given out a strong sulphureous smell; flashes of lightning issued from it, and threw off a great quantity of water. It moved forward in one direction over high grounds and valleys, and it crossed the course of a river, but on coming to hills of a conical form, it passed round them. The alleged sulphureous smell was no doubt that of the electric *aura*, so called, perceived when lightning has taken effect very near the observer, and probably often that of ozone in reality. Waterspouts have occasionally been witnessed in this country. In 1718 one of them burst in Lancashire, when, at the place where it fell, the ground was torn up to the extent of about half a mile in length, and to the depth of seven feet, so as to lay bare the surface of the rock underneath. ('Phil. Trans.,' No. 363.)

The formation of waterspouts has been ascribed to a whirling motion produced in the air by currents coming in opposite directions; it has been supposed that the particles of vapour in the upper regions thus acquire, by the centrifugal force, a tendency to move towards the exterior parts of the column, leaving the interior void or in a rarefied state. The pressure of the atmosphere being thus removed from the surface of the sea or ground immediately below, that which takes effect on the surrounding water (when the spout is formed at sea) must impel the latter towards that part, and cause it to rise into the space where the partial vacuum exists. There is great probability that the elevation of the sea under the cloud is in part caused by the rarefaction of the air; but as the pressure of the atmosphere could only raise the water in a perfect vacuum to the height of about 30 feet, and as the height of a waterspout is known to be sometimes about half a mile, some other explanation of this part of the phenomenon must be sought for.

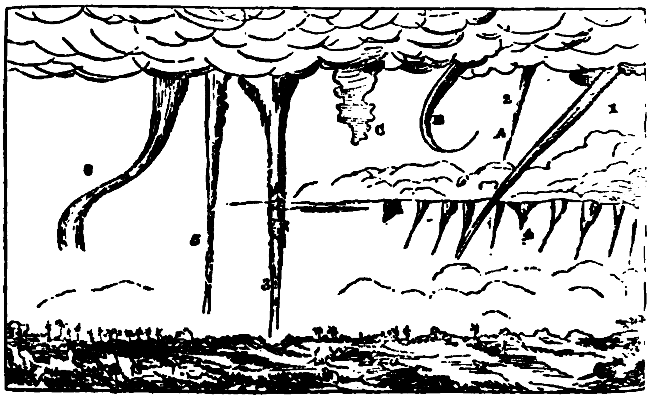
Some valuable observations on waterspouts formed over land have been recently made by Major Walter S. Sherwill, an officer to whom we are indebted for various contributions to science, respecting the physical geography and meteorology of India. Among other instances, he has described in a very instructive manner a waterspout of colossal dimensions which was seen to form and burst at Dum Dum, eight miles north-east of Calcutta, on the 7th of October, 1859. The circumstances preceding and attending the phenomenon were as follows:—

The south-west monsoon [MONSOON] during the week had received its first check by the north-east monsoon endeavouring to cross the Himalaya mountains, and to drive back the heavy masses of clouds "and moisture" (probably clouds becoming floating small rain, having the aspect of mist) that had been banked up along their flanks during the whole of the rainy season, or during the prevalence of the south-west monsoon. At Dum Dum, the visible heavens were wholly occupied by a dense mass of very grandly shaped and massively grouped strata of cumuli [CLOUD] at various elevations; the lowest stratum, from actual measurement by Major Sherwill, was 2000 feet above the earth, the highest probably reaching the altitude of 25,000 feet, the entire mass being about five miles in vertical thickness. The aspect of the heavens during the past few days had been most remarkable, presenting a scene of great disturbance; the clouds, evidently impelled from the south by the south-west monsoon, but, checked by the north-east, the whole mass, extending for as many miles as the eye could reach from north to south and from east to west, acquired a rotary and at the same time an undulatory motion; huge tracts of clouds revolving rapidly around a centre which appeared, from the observer's position, distant about 1¾ mile from Dum Dum, to be about 5 miles to the south-east. This rotary motion, performed in a very large circle, gave the clouds the appearance of moving in two distinct directions, those nearest to the observer appearing to be going north, and those furthest removed to be going south. In the early portion of the day, the wind had been from the south, bringing with it from the sea a large body of clouds; at noon it changed to the south-west, at 2 P.M. to the west, and at 4 P.M. to the north: there had been but little rain during the day.

The greatest disturbance in the clouds took place between the hours of three and four, the whole mass revolving and heaving violently; extensive masses of clouds were crushed and driven into others, but no lightning was observed. It now rained heavily to the north and east. "During this time," Major Sherwill says, "more than one waterspout endeavoured to form, but unsuccessfully. It was whilst observing the highly-agitated masses of clouds that were revolving and oscillating in a most peculiar manner, that I witnessed the commencement and termination of the remarkable waterspout now under consideration. At three P.M. it became suddenly quite calm, and during the calm a pale watery-looking, but very watery, cumulus, the base of which was a right line, and parallel to the horizon, was seen to bulge out downwards or towards the earth in a long well-defined and light blue coloured outline; from the centre of this hanging curve a broad column of a pale watery vapour rapidly sank towards the earth, closely resembling a very attenuated cone, dark at the edges and pale blue in the centre, plainly showing it to be a solid cylinder; as it neared the earth the lower half of this elegant column commenced to gyrate rapidly, the lower end oscillating violently to the right and to the left; this latter movement I imagine to be a mere optical illusion, caused by the lower end of the column revolving in a circle of large diameter; as the column neared the earth it expanded and contracted in an agitated and rapid manner about the centre into cloud-like protuberances, which partook at the same time of the motion of the revolving column. Upon arriving nearer the earth the end of the column parted into two slender columns about 150 ('or 200,' as stated in another place) feet each in length, and in this condition reached the ground. The shape of the column was now completely and instantaneously altered; for the whole cumulus burst, and was seen pouring down to the earth, not as a shower of rain, but as a heavy mass of water, resembling a waterfall more than a shower of rain, that completely exhausted and brought the whole cloud to the ground in a few seconds of time."

The estimated length of the cumulus, the lower portion of which had become a heavy nimbus, from which the waterspout depended, had been 3000 feet, and its height, from base to summit, 5000 feet. By trigonometrical means, Major Sherwill ascertained that the perpendicular height or length of the column or waterspout itself, from the point of its protrusion from the clouds to its lowest extreme point at the moment of bursting, was 1500 feet. Its period of duration, from its first formation to its bursting, was about 25 seconds. It burst upon the artillery practice-ground, a large grassy plain, of which it covered half a square mile with water to the depth of about half a foot, which took fourteen days to drain off by the usual drainage courses of the country. The cattle fled in all directions as it descended, but no noise was heard at the observer's position.

Major Sherwill's observations are illustrated by excellent lithographic representations of the waterspouts he observed. Some of these are somewhat roughly copied in the subjoined diagram, in which *fig.* 3 represents the waterspout now described. Half an hour after this had disappeared, he relates, "another formed to the east of the position: it was a very attenuated column, about 900 or 1000 feet in length, but the cloud from which it descended being upwards of 2000 feet above the earth, no contact was completed; the column, which lasted for half-an-hour, gradually faded away, being absorbed upwards into the cloud from whence it had descended. The cloud and column were moving rather rapidly towards the south, which probably accounts for the column never reaching the ground. The column gyrated and oscillated violently, lengthening and contracting as shown in the diagram (*fig.* 4), where eleven different positions of the column are given, sketched at intervals of from two to five minutes. Towards sunset, the clouds began to yield to the north wind, and were gradually driven out to sea, leaving a clear cloudless sky; and at nine o'clock at night not a cloud was to be seen. The north-east monsoon had fairly set in.



The following are the particulars of the other four waterspouts figured. *Fig.* 1. Seen from Sooksagur, 35 miles north of Calcutta, on the 27th September, 1855, at 3·30 P.M. Estimated length, 1000 feet. Moving south. Dependent from a heavy nimbus at an angle of 45° with the horizon. Upper portion gyrated rapidly. Lasted ten minutes. Did not burst, but was absorbed upwards. *Fig.* 2, A, B, C. Seen from Howrali (Calcutta) 24th September, 1856, P.M. Estimated length, 200 feet. Moving north. Depended from a very heavy and stormy looking nimbus, accompanied by vivid lightning. It was greatly agitated, throwing its lower end horizontally to the south, then to the north, at an angle of 45°; lasted about five minutes, and burst into heavy deluging rain.

Fig. 5. Seen from Dum Dum, and from Calcutta, on the 11th of August, 1860, at 5 P.M. Estimated length, 1000 feet. Moving south. Very perfect and grand. Depended from a heavy nimbus, unaccompanied by lightning. Gyrated rapidly at the top, dark at the edges and pale blue in the middle. "Divided at the lower end into two smaller columns of 50 or 80 feet in length." Lasted about ten minutes, and burst into heavy rain.

Fig. 6. Seen from Sulked, (Calcutta) on the same day, and at the same hour as the last; crossed the river Hooghly at that place, agitating the water beneath it. Estimated length 800 or 900 feet. Moving north-west. Depended from a heavy nimbus. "Had hanging fringe-clouds, dropping rain, on the south side of the upper part of the column." Gyrated rapidly at the summit of the column. Was bent by a south wind into an elegant double cone resembling the letter S. Lasted about ten minutes. Superior portion absorbed upwards, lower part burst into heavy rain. The figures in the diagram, it must be stated, have a more defined outline, and a greater appearance of solidity, than in the original lithographs.

Major Sherwill, in conclusion, has briefly described and also figured two other waterspouts, both attended by or exhibiting remarkable and instructive phenomena. One of these was seen by him from Darjeeling, in the Himalaya, on the 29th of May, 1852, at noon. This was a warm dry summer day, highly favourable to evaporation; and the invisible vapour with which the air had become charged was suddenly condensed, by a chilled stream of air descending from the snowy range of the Himalaya, distant 35 miles, into a huge cumulus cloud, at an elevation of 11,000 feet. The first effect of the cold blast was the formation of a small cloud "the size of the hand," which rapidly increased until it extended to the length of 15 miles and the vertical thickness of 5000 feet, or nearly one mile. This body of cloud was driven with great celerity to the south; and as it approached the mountain Ponglo (distant 11½ miles from Darjeeling, and slightly exceeding 10,000 feet above the sea) the lower portion, hitherto nearly horizontal, began throwing down about twenty waterspouts, each 1000 feet in length, which gyrated at a rapid pace, increasing in length at the same time, until the whole cloud burst into heavy rain. "The summit of the mountain," it is observed, "was evidently a point of attraction for the electricity contained in the cloud, as the waterspouts one mile north and south of the central group descended towards the mountain at an angle of 45° with the horizon, and all seemed striving to reach the very summit of the mountain; and upon reaching it they all burst into heavy rain. Time of duration, fifteen minutes." The other, and the last waterspout of Major Sherwill's list, was observed and sketched by the Rev. R. A. H. Norman, at Dum Dum, on the 28th of October, 1860. It was a group, depending from a heavy nimbus, and consisting of one central and large spout or column, 1500 feet in length, flanked to the eastward by many smaller ones, some of them 500 feet long, which were absorbed into the main column as fast as they were formed. Between the nimbus and the mass of light haze that covered the horizon, a long slip of blue sky was visible, and the waterspout, where it crossed this, was invisible, appearing as if the whole was divided into two portions. The entire group lasted twenty minutes, and eventually burst into heavy rain. ('Proceedings of the Asiatic Society of Bengal,' Sept. 5, 1861, Journal, new series, vol. xxix., pp. 366–375, 418, 419.)

The manner in which several of the waterspouts described by Major Sherwill burst into rain on coming into contact with the earth, is strongly indicative of electrical agency, to which, indeed, these phenomena, with more or less of vague conjecture or more or less of science, have long been attributed, and which may be both cause and consequence of the mechanical actions to which, in the former part of this article, they have in part been referred. The circumstance just mentioned points to an extension of the cloud towards the earth caused by electrical attraction, between two surfaces (those of the cloud and the earth), one of which has been charged by the other by induction, until, by the contact, a discharge of the electricity takes place, and the particles of water previously charged are at once precipitated upon the earth. Under other circumstances, the attractive force of the earth ceasing, or being insufficient, the spouts are absorbed into the cloud again by the force which holds the cloud together. But the column or spout itself, being colourless and transparent, when viewed by transmitted light, would appear to consist, not of cloud, but of water, nearly in the state of rain, and bristling into it on the discharge taking place. The entire system of cloud and water, and the flooded earth also, being one of excellent conductors of electricity, the discharge is comparatively or altogether silent.

Strong corroboration of these inferences as to the electrical production of waterspouts, may be found in their observed production in the sequence of the phenomena which attended the submarine volcanic eruption by which the temporary island, Sabrina, was elevated from the bed of the ocean, near St. Michael's, in the Azores, from the 9th to the 12th of June, 1811; the important bearing of which on this subject seems, hitherto, to have escaped attention. Captain Pillard, R.N., who witnessed the eruption, describes (under the name of smoke, like all other observers of volcanic eruptions until Mr. Poulett Scrope had shown it to be condensing steam), the immense steam-cloud issuing from the sea, which constituted a part of the eruption, together with, and through which the columns of stones, cinders, and ashes—the comminuted lavas—were projected in rapid succession. "During these bursts, the most vivid flashes of lightning continually issued from the densest part of the volcano; and the cloud of smoke [steam] now ascending to an altitude much above the highest point to which the ashes were projected, rolled off in large masses of fleecy clouds gradually expanding themselves before the wind in a direction nearly horizontal, and drawing up to them [and being drawn down into] a quantity of waterspouts, which formed a most beautiful and striking addition to the general appearance of the scene." These, according to the particulars stated ('Phil. Trans.,' 1812) must have been from three or four hundred to eight or nine hundred feet in height or length.

We have here, palpably, all the elements for the electrical causation of waterspouts—the immense evolution of electricity [VOLCANOES, col. 660], the charged surface of cloud, the dielectric atmosphere, the surface of sea below—and the actual production accordingly, of the phenomena sought to be accounted for. Much more might be said on this branch of the subject, which indeed is one of great extent and complication, the explanation now suggested being of a general nature only.

Much valuable information respecting waterspouts was introduced by the late Mr. Piddington, into part 5 of his 'Sailor's Horn-Book for the Law of Storms,' including a view of the contents of M. Peltier's work entitled 'Observations et recherches expérimentales sur les causes qui concourent à la formation des Trombes,' under which appellation whirlwinds and waterspouts are identified by the author; being applied, indeed, to them indifferently and convertibly, by French writers in general.

To a portion of this part of the subject we shall return when considering cyclones and whirlwinds in the article WIND.

WATER SUPPLY. The improvements which have lately been effected in the practical details of civilised life, have given rise to so great a demand for a copious domestic supply of water, that the branch of hydraulic engineering connected with that portion of modern social organisation has assumed a degree of importance, in excess even of the importance attached to it by the most civilised nations of antiquity. Yet from the earliest periods in the history of man, the attention of the governors of populous cities has been always directed to providing for them copious supplies of the fluid so indispensable for comfort, cleanliness, and safety; and no surer test can be found for the character of a national organisation, so far as its influence upon the physical happiness of its subjects is concerned, than the one to be discovered in the state of the water supply of its towns. Some of the lessons to be derived from an examination of the various systems hitherto adopted will be alluded to in the course of the following review of their history.

There are few indications left of the existence of a complete system of water-works in the ruins of the Assyrian, or of the Babylonian towns, although the numerous traces of canals upon the banks of the Tigris and Euphrates show that great attention was there paid to the irrigation of the land, and to securing a copious supply of water. In Egypt, the same conditions appear to have prevailed, and numerous canals were formed for the purpose of leading the waters of the Nile to tanks, and wells, situated at distances from the shores of the stream; but the water was not habitually raised to any height, unless in gardens, and then only in small quantities, and by very rude machinery. It is interesting, however, to observe that the hieroglyphical paintings of the Egyptians represent the use of the *shadouf*, or of the balance pole and bucket, still retained in that country, and by the market gardeners of the neighbourhood of London. The *noria* was not known to, or used by the ancient Egyptians, although so universally employed in that country at the present day; but Diodorus mentions that the machine known by the name of the Archimedean screw was invented by them. In Phœnicia, and in Judæa, traces of aqueducts, of tanks, and of wells, are frequently to be met with; and in those countries the first indications of works designed for the purpose of conducting the waters which outburst at a high level at some distance from the proposed place of consumption, may be observed. There were no pipes used in any of these water-works, or conduits; and the first instance on record of their application is to be found in the ruins of the aqueduct of Patara, in Lycia; upon which line there is a singular wall, or embankment of rough stone, across a valley 250 feet deep, and 200 feet across, bearing upon its curved top a line of marble blocks cramped together and perforated, so as to form, in fact, a reversed syphon. It would seem that the defective state of the metallurgic arts, alone retarded the application of the principles of hydrostatics known to the more ancient nations of the East; for the hieroglyphical paintings of Egypt certainly show that the syphon and the ordinary forms of pipes were occasionally employed by them; and the aqueduct of Patara equally proves that the Greeks were aware of the law by which water rose to equal heights in the two legs of a reversed syphon.

It was, however, under the dominion of the Romans that the ancient world undertook the most gigantic works for the supply of their towns with water; and, fortunately, the writings of Vitruvius, Frontinus, and Palladio have transmitted to our days much curious information with respect to the detailed methods of execution adopted by the Roman engineers. According to Frontinus, the inhabitants of the Eternal City for a long time contented themselves with a supply of water obtained from the Tiber, from land-springs, and from wells; but about the year 312 B.C., the censor Appius Claudius completed the first aqueduct, subsequently known as the *Aqua Appia*, which conducted to Rome the waters of a spring rising "in the field of Lucullus, between the 7th and 8th *milliaria* of the Prenestine road." Subsequently, the aqueducts of the Anio Vetus, Aqua Marcia, Aqua Tepula, Aqua Julia, Aqua Crabra, Aqua Virgo, Aqua Alsietina, Aqua Augusta, Aqua Claudia, Anio Novus, and the A. Alexandrina were added to the means of supply; and in the later days of the empire the daily distribution of water amounted to the enormous quantity of 332,307,624 gallons. As the population of Rome does not appear to have attained 1,000,000 under Aurelian, according to the calculations of M. Letarouilly, the average supply must have been about 332 gallons per head per day; but as the registers of the distributions show that only one-fifth of the total quantity was taken by private consumers, it must be evident that the bulk of the water was devoted to the public fountains, baths, gardens, and amphitheatres, &c. The text of Frontinus contains many curious details with respect to the manner in which the house services were connected with the reservoirs, or distributory cisterns; the regulation of the plumbers' works; and the precautions observed to insure the coolness and purity of the water; and there are few books illustrative of the manners and customs of the Romans which give so curious an insight into their municipal life as the 'Commentaries' of this author. It may be added that the total length of the eleven first-named aqueducts was not less than 456,987 yards, of which 53,421 yards were built upon arches. The highest point of ground in the city was the Mons Esquilinus, which was 144 feet 8 inches above the level of the invert of the Cloaca Maxima, but the aqueduct of the Anio Novus discharged its waters at the level of 155 feet 10 inches above the same datum. The flow of the waters attributed to the public service was constant, by night as well as by day; and the private consumer had the same privilege if he desired it.

The Roman emperors were far from confining their attention to the water supply of Rome itself, for numerous and gigantic works of that description, for the supply of important provincial towns, were executed by their orders. [AQUÆDUCT.] During the decline of the lower empire, even, the construction of aqueducts and of reservoirs was carried on with the same degree of energy as in the brighter periods of the Roman rule; and the neighbourhood of Constantinople possesses ruins of the aqueduct of Justinian, and in the valley of Bourgas, which may rival any of the earlier structures in magnitude at least, if not in constructive skill. Perhaps the most remarkable parts of the water-works of Constantinople were, however, the subterranean reservoirs there constructed to store the water. One of them is about 319,200 cubic feet in capacity, and the other about 1,028,970 cubic feet, and they are vaulted throughout.

Of course the art of distributing water suffered under the effects of the irruption of the barbarians; and all that was done by even the most enlightened of the rulers of the Gothic, Vandalic, and Lombardic tribes was to repair and maintain the aqueducts they found to be in existence when they overran the provinces of the Roman empire. There is a tradition connecting the erection of the aqueduct of Spoleto with the name of Theoderic the Goth; but the style of the monument, and many other indications it furnishes, would throw great doubts on the correctness of the story; nor can we discover any authentic records of the execution of any great works for the supply of water to towns during the mediæval period, until about the end of the 13th century. In fact, the great centres of population in modern times were but very insignificant villages in the early periods of history; and property was held by far too uncertain a tenure to justify the execution of great public works. The Italian cities seem to have been the first to attempt anything like a systematic distribution of water; and Michael Boccanegra, at Genoa, in 1278, the unknown authors of the Spoleto and of the Civita Castellana aqueducts, at other periods in the Middle Ages, revived the modes of construction adopted by the Romans. In the north of Europe there do not appear to have been made any attempts to rival the gorgeous monuments of the Roman empire; and in nearly all cases—as at London and at Paris—the system adopted seems principally to have been to lead to some stone reservoirs the waters of springs rising in the country, by means of wooden or of leaden pipes. When the populations of those towns had increased to a considerable extent, it was found, however, that, as in the former case of Rome, it was no longer possible to obtain the necessary quantity of water from the superficial gravels, or from the water-bearing strata around them; and we accordingly find that at the close of the mediæval period efforts were made to secure water-supplies to the large towns from larger areas than had previously sufficed. In France, the engineers seem to have considered themselves bound to return to the traditions of the Romans, and the aqueduct of Arceuil was built in avowed imitation of the analogous structures of the ancients. In England, the system of contouring the hills by open water-courses prevailed; and the Plymouth Leet, established by Sir F. Drake, and the New River by Sir H. Myddelton, may be cited as illustrations of the system long adopted here. The great aqueduct of Lisbon, erected between 1713 and 1732; the aqueduct of Caserta, erected by Vanvitelli about 1753; the aqueduct of Symete, erected by Prince Biscari, in Sicily; the Croton Aqueduct, and the Roquefavour Aqueduct, may be referred to as illustrations of the modern execution of works for the supply of water, designed upon the principles of the ancients; but the majority of the modern water-supplies are executed in a far less ostentatious manner, and with modifications required by the local habits or by the municipal organisation of the towns themselves. Of late years, also, the improvements which have been effected in the machinery used for the purpose of raising water, and the new applications of metallurgy to the building arts, have so profoundly changed the economical conditions of the distribution of water, that it is hardly possible to compare the systems which have respectively prevailed in ancient or in very modern times. The fundamental difference seems, however, to consist in this, namely, that the state undertook the execution of the water supplies of antiquity, whilst in modern times they have been left entirely to municipalities or to private industry. What the moderns may have gained in economy under these circumstances, they have lost in art; and just precisely as the economical element of the calculation prevails, so does the manner in which a modern water supply is effected lose all character of beauty as a monument.

Before entering upon the consideration of the technical questions connected with the subject of a water supply, and before quitting the past history of those operations, it may be desirable again to dwell upon a very generally received opinion with respect to the assumed ignorance, by the ancients, of the principle of the inverted syphon; or of the principle by which water will find the same level at the two ends of a continuous pipe, unless prevented by some external force. This opinion has been repeated in so many popular works upon science, that it is almost universally believed; yet, not only does the aqueduct of Patara entirely refute it, but the great syphon upon the course of the aqueduct of Lyon proves that the ancients were as well acquainted with the principle as the moderns themselves are. It is the more extraordinary that this singular opinion should have obtained such universal credence as it has done, because Vitruvius discusses in a very practical spirit the mode of executing the descending and ascending pipes, in chap. vii. lib. 8; and he points out the precautions to be taken to prevent the rupture of the pipes by the compression of the air in the lowest parts of the syphon.

The first inquiry at the present day, when it may be desired to execute a system of water supply to a town, after having ascertained the present and the probable future extent of the consumption (which is usually reckoned to take place at the rate of forty gallons per head of the population per day), must of course be, as to where a permanent supply of water of a proper quality is to be obtained. Much discussion has of late years taken place with respect to the question as to what constitutes the proper quality of such a water, and the formerly received opinions of physiologists and engineers have been boldly challenged by men who have had little claim to either of those titles. The discussion has principally turned on the subject of the hardness and of the softness of waters, consequent upon the presence in them of the salts of lime, in the form of the bicarbonates of that base; the former authorities upon such matters contending that a certain proportion of lime is necessary in a potable water, whilst the new lights contend that absolute purity should be aimed at. The truth, in this case, seems to be that there is still too considerable an amount of uncertainty with respect to the real action of the salts in question upon the human frame to allow of the formation of any very decided opinion on the subject, or of the establishment of any absolute law for the adoption, or rejection, of a particular source of supply, when its departure from the standard of absolute purity is very small. Local considerations of economy must, in the present state of knowledge, exercise great influence upon the choice of the source of supply; and it is only when the quantities, or some peculiar properties, of the extraneous impurities, are very objectionable, that it becomes desirable to reject a source which is close at hand. The qualities which are indispensable in a water designed to be distributed in a town, are, to quote the words of the 'Annuaire des Eaux de France,' that "it should be fresh, limpid, and without smell; that its flavour should be hardly perceptible, and that it be neither disagreeable, flat, brackish, nor sweet; that it should contain little foreign matter, but a sufficient quantity of air in dissolution; that it should dissolve soap without leaving curds, and should cook vegetables easily." A small portion of carbonic acid gas increases the wholesomeness of a water, by its influence upon the digestive organs; but it enables the water to take up an additional quantity of the salts of lime (which in their turn increase the hardness of the water), and to develope some forms of disease (such as gout, calculi, &c.) in the populations using it habitually. Waters containing salts of magnesia, or of sulphate of lime, are considered, on the other hand, to produce the loathsome disease, the goitre; and the very purest waters obtained from the melting of ice, or of snow, are deficient in some elements necessary to maintain the healthiness of the human frame. The waters which hold in solution notable proportions of organic matters, are, however, those which are the most objectionable; and diarrhœa, dysenteries, and other acute and chronic diseases may be traced to the use of the water obtained from ponds, marshes, or wells, containing excessive proportions of altered organic matters, either in suspension, or in solution. It was considered, by the authors of the 'Annuaire des Eaux,' that the small quantity of the chloride of sodium to be found in ordinary river or spring water was rather advantageous than otherwise; and they further remark, that the chlorides in water are almost always associated with the iodides and bromides, which unquestionably increase its salubrity. It may be added, that when the proportion of the bicarbonate of lime in a potable water exceeds 1 in 2000, it becomes positively injurious; that the bicarbonate of lime is thrown down by boiling; but that neither the salts of magnesia, nor the sulphate of lime, are thus expelled.

The opinion which it has lately been attempted to convert into a law, "that the nearer the source, the purer the supply," seems to be one of those half-truths which require to be accepted with a reservation. Thus, the waters rising from deep-seated springs in the chalk formation contain at their source an abnormal dose of the bicarbonate of lime, which they part with if allowed to flow in the open air in a clear channel. Indeed, so much do waters generally improve by the flow in open channels, that some of the ablest physiologists hold that river waters alone should be used for town supplies; but in such cases, it is essential to adopt precautions with a view to the prevention of the contamination of the latter, by the organic impurities washed down from the lands they traverse. A prolonged course over a rough channel also removes earthy impurities, and the hydrous oxides, which are often held in suspension in spring waters; but it does not seem to have any influence upon the sulphates of lime, or of magnesia, or upon the chlorides of calcium or of sodium. In all cases wherein such a course is able to do good, it must, however, be observed, that the water must flow with considerable velocity; and it would appear that the aëration of the water thus produced constitutes one of the superiorities of river waters over those obtained from ordinary wells; because the latter are exposed, occasionally, to become stagnant. When a water supply has to be obtained from a great distance, the considerations of the deposition of the earthy salts become of great importance, on account of the effect they are likely to produce upon the delivery of the conducting channels; and it was precisely because the engineer of the Marseille waterworks, M. de Montricher, feared that the waters of the Durance would choke a reversed syphon that he was led to erect the gigantic aqueduct of Roquefavour. The channel through which any stream is to be led must, it may also be added, be protected from accidental impurities derived from the atmosphere, or from any other source; and even at the present day, the hydraulic engineer might derive many useful lessons from the practice of the Romans in these details of their aqueducts. They took care, in fact, to cover their channels as far as possible; to provide ventilating shafts from distance to distance; and to place drips in the line of the invert, in order to produce small cataracts, with a view to increasing the aëration of the water.

The objections to the use of ordinary well-waters, on account of their tendency to become stagnant, apply with variable force (according to the quantities considered) to the waters of ponds, of reservoirs, or of lakes; and therefore they have an important bearing upon the system of the supply to towns, known in England by the name of the "*catch-water gravitation system.*" In works of this description, the water, falling upon elevated districts around the town to be supplied, is stored in large artificial reservoirs, in such a manner as to allow the excess of the winter's rains to be distributed in the dry season; and evidently these reservoirs must be established so as to ensure the disposal of the maximum quantity for distribution precisely at the season when there would be the least rainfall to renew the water. During the dry season, in fact, the water in the reservoirs cannot be renewed, and it must be exposed to all the deleterious actions which are known to take place in stagnant water from the development of animal and of vegetable life in them, under the influence of light and heat. The purity of the waters thus stored must, however, depend greatly upon the nature of the surface from whence they flow, upon the nature of the soil of the reservoirs themselves, and upon the exposure, the outline in plan, and the transverse sections of the reservoirs; for the primary qualities of the water depend on the first of these considerations, and its preservation in a wholesome state depends greatly upon the influence of the latter in maintaining a surface agitation. The lands which exercise the most deleterious action upon the waters to be impounded are those which are covered by peat, or by agricultural land; or those which are likely to give off mineral or earthy salts in large quantities; and, therefore, the primary or secondary crystalline rocks and the pure silicious sands are the best adapted for the purpose of forming gathering-grounds. In England, and in most countries where gravitation waterworks can be established from reservoirs, such as are above alluded to, it fortunately happens that the gathering-grounds occur in the hilly districts of the primary formations; but in India, and in tropical alluvial plains, it is often necessary to store the excessive rainfall of the wet season in *tanks*, for consumption during the dry season, because the superficial water-courses cease to yield water, and there are no perennial springs in such districts. The waters so stored must, under these circumstances, be filtered, or treated in some way, in order to counteract their otherwise deleterious effects upon the human frame; the great difficulty, however, arising from the temperature to which they are raised by the sun's action upon their surface.

It would appear, after all, that the waters which unite the greater number of favourable qualities for a town supply are those which flow from deep-seated springs, or from the insoluble clay slates, crystalline limestones, or are obtained by continuous pumping from wells sunk in the pure silicious strata, &c. It is not often that these wells yield water in sufficient quantities for a town supply; and there is always a danger of their being interfered with by the operations of neighbours, or by injurious infiltrations from cesspools or dead wells. The history of the Artesian wells round London, of those at Tours and Paris, and of the deep wells in the new red-sandstone at Liverpool, proves that there are serious objections to allowing the supply of a large population to depend on sources so uncertain, and so easily diverted, as these deep-seated springs evidently are. In no country in Europe is there any legislation creating a right of property in underground waters; for law-makers have not hitherto been geologists, and they have openly avowed their ignorance of the principles which regulate the flow of deep-seated springs. It thus happens that the inhabitants of large towns are compelled, practically, to resort for their water supply either to rivers or superficial water-courses, or to create reservoirs upon either the gravitation or the tank system, to impound the rainfall of the wet seasons.

In the previous portion of this article it was stated that the quantity of water to be distributed in a town was usually calculated at the rate of 40 gallons per individual per day; but evidently local circumstances may affect this rate of consumption to a very serious extent. It is more than questionable whether even the most luxurious persons require absolutely a greater quantity than 6 gallons per day for their own immediate consumption; and if the latter be carried to 10 gallons per day, it would suffice with proper care for any real demands. In calculating for a town supply, it is necessary, however, to allow for the consumption by trades using large quantities of water, and for municipal purposes, such as street-watering, flushing sewers, extinction of fires, &c.; and, in order to cover these demands, it was considered, so long as the old-fashioned intermittent supply existed, that an allowance of 20 gallons per head per day would be sufficient. The introduction of the constant-delivery system has of late years tended singularly to increase the quantity of water distributed, and indeed the waste of water which thus takes place is at times so great that it almost assumes the importance of a public calamity. In London, where the intermittent supply still prevails, the consumption of water is now not less than at the rate of 40 gallons per head per day on the average; in Croydon, at Boston, New York, &c., the rate under the constant delivery has been 80, 100, and even sometimes 500 gallons per head per day. No doubt a great part of this waste could be prevented, and it would never be allowed to exist if the water supply of towns were left in the hands of private companies; but the tendency of the age is certainly to withdraw municipal services from the control of speculative adventurers, and it therefore becomes important to direct attention to the eventual danger arising from the waste which seems to be inherently attached to the modern system of distribution.

Whatever may be assumed to be the normal rate of consumption by the inhabitants of a town, it must be observed that, in the summer months,—that is to say, in June, July, August, and September,—the average consumption per individual per day increases in about the ratio of 10 per cent. upon the ordinary average; whilst in December, January, and February it is about as much below the same average. In designing gravitation-works, especially, this becomes an important consideration; for the consumption actually increases when the supply decreases, and the dimensions of the reservoirs must be calculated of sufficient size to meet the demand of the season which is the most unfavourable. The compensations to be given to the ancient possessors of water privileges must also be taken into account in designing any new water-works, especially in the case of gravitation-works, which interfere more with the natural hydrographical conditions of a district than ordinary pumping-works do; and the loss of water by evaporation from the reservoirs in hot weather requires also to be allowed for. In most countries of Southern Europe, it is to be observed, moreover, that the rate of personal consumption of water, so to speak, is much less than the rate prevailing in the north, but that the quantity of water poured down the channels, or used in the monumental fountains, or in other contrivances for cooling and refreshing the air, is, on the contrary, very much greater. Thus, in Paris, it is stated officially that the supply of water takes place at the average rate of 13¼ gallons per head per day; but, in fact, the water is sold by the pail, and in no house in Paris is there a supply (in 1861) to the second floor, and nearly all the water which is brought into the city is poured into the street kennels or is employed in the fountains. All these details of the application of a town supply must, therefore, be carefully examined, and allowed for, in selecting the source and mode of distribution; for it must be evident that every particular climate, and every phase of civilisation, requires to be treated upon its own special principles.

The quantity and the quality of the water supply being determined, a very important question arises, as to whether it should be obtained, at a great original outlay, under such conditions as to allow the water to flow to the place of distribution, by gravitation; or whether it should be obtained by means of pumping-machinery, at a smaller original outlay, but at a greater annual expense for working. This question is one which it is impossible to decide *à priori*, because it must be so materially affected by local considerations as to render it dangerous to lay down any absolute rules in the matter. But it must be evident that, wherever it is possible, as it was in the case of ancient Rome, to lead into a town streams of water rising at a natural elevation above the proposed points of distribution, there must be an eventual economy in so doing over the cost of another system by which the water would be raised from even a nearer point by the aid of a complicated piece of machinery. The Romans, who were able to concentrate upon any work they undertook the resources of the known civilised world, adopted the former system; and the highly-centralised governments of modern Europe evidently prefer it, for the French are about to incur an enormous expense in order to lead to Paris, by gravitation, some springs which rise at a great distance from that town. In England and in America, however, where individual enterprise is so much more active, the tendency is to resort to sources of supply which admit of the application of machinery at a small primary outlay; and, in fact, the choice between the two systems must greatly depend upon the power of commanding capital, and upon the balance of motives which might lead to imposing a burden upon the present generation for the sake of its successors. In either case, the works required for the filtration, storeage, and distribution of the waters are the same; the only difference consists in the mode of leading the water to the point from whence the distribution is to take place.

Even in gravitation works there are various methods of solving this question, for the water may be led either in closed pipes or in open or in covered conduits. Open conduits may be resorted to when the district they traverse is not likely to furnish any elements of a nature to alter the purity of the water; but if small local watercourses should be likely to pour into the stream, or if the latter should be exposed to the danger of contamination from the dust, smoke, or other impurities of a town atmosphere, the conduit must be covered. The advantage of a pipe-conduit consists precisely in the protection it affords against such accidental sources of contamination, and, generally speaking, it will be found to be cheaper than a masonry conduit of ordinary dimensions. Moreover, the facility the pipes furnish for the execution of reversed syphons dispenses with the necessity for the construction of costly aqueducts. It is essential to make the dimensions of the pipe somewhat larger than would theoretically be necessary to convey the quantity of water required to be delivered; because there is a danger, in almost all cases, of the formation of an incrustation in the interior of the pipes, which would practically diminish their sectional area; and it is essential, also, to provide means for occasionally examining and clearing the pipes. In all descriptions of conduits it is necessary to provide stop-gates, or valves, and overflows, so as to arrest the passage of the water in case of accident. The material generally used for pipe-conduits is cast-iron; but glazed stone-ware is often employed with success, when the water does not flow under great pressure. The Romans frequently used lead-pipes for this purpose; but as a general rule they preferred covered aqueducts, and the Continental engineers still adhere to this system. In the great Liverpool gravitation water-works, and in the new supply to Glasgow from Loch Katrine, cast-iron pipes have been exclusively used where any great differences of level have been encountered.

In the majority of cases at the present day, the water brought from a distance for the supply of a town, is filtered before distribution; and this is effected in positions as close as possible to the pumping station, or to the entry of the distributing mains, unless the water should be so pure naturally as to allow this precaution to be dispensed with. There are numerous systems of filtration in use in England, but the one most generally adopted is to cause the water to pass through a succession of layers of sand and gravel (increasing in coarseness from above downwards) to a series of drains leading to a covered reservoir. The total thickness of the filtering media is usually made from six to seven feet, and the number of layers about eight or nine, the head of water over the upper surface of the sand being about two feet. Engineers, however, are not unanimous in their opinions as to the best relations between the depth of the filtering media and the head of water over them; for in some cases the depth of the sand and gravel is made only 4 feet 6 inches, and the working head four feet, instead of the dimensions quoted above; but evidently the degree of purity of the water itself must materially affect this question. It may even happen that the quality of the water may require the introduction of some ingredient in the filtering media which should be able to exercise a chemical influence upon the water itself; and in some cases it has been proposed to mix animal charcoal with the upper layers of sand, in order to remove any organic matters; or to mix the magnetic oxide of iron with the sand when peaty matters are present; or even to apply Dr. Clark's process when the bicarbonate of lime is present in notable excess. Local considerations must guide the engineer in his choice of the various systems; but however the water may be treated in this stage of the distribution, it is absolutely necessary that it should not be exposed to the air at all after having been filtered, and that it should be either at once passed into the distributing mains, or be stored in covered reservoirs until wanted for use. In the construction of the latter, the only important observation to be made is that they must be executed in such a way as to protect the water against the action of light and of the sun's rays; local facilities for the supply of building materials must regulate the precise details of the construction itself. In some peculiar cases it is desirable to provide, in addition to the filters and pure water reservoirs, depositing basins, in which the heavier materials, in mechanical suspension in the waters of the natural source of supply, may deposit themselves; but, again, this detail admits of no universal law; and it is even to be observed that the tendency of the London engineers is rather towards the suppression of both depositing basins and storeage reservoirs. They make the filters of sufficient area and thickness to complete rapidly and effectually the separation of the impurities; and they pump the filtered water at once into the distributing mains. Where storeage reservoirs are used, their dimensions may vary between the capacity required for three days' consumption, when the source of supply is liable to occasional interruptions; and the capacity required for a few hours' supply when the machinery is only subject to ordinary periods of rest or repair. In the latter case it may be necessary, however, to make the machinery in duplicate, or at least to keep a stock of duplicate parts. Care must be taken to provide for all such service reservoirs, valve pits, overflow pipes, waste weirs, scouring pits, and other conveniences for examination, cleansing, and repair.

Unless in the cases of gravitation works, it is necessary, in all modern domestic water supplies, to raise the water to such heights as to allow of its distribution in the loftiest rooms of the houses situated on the highest ground in the respective towns, by some description of machinery. When the quantity to be raised is small, and there is a watercourse of considerable volume, and great constancy of flow, in the neighbourhood, it may often be advisable to resort to hydraulic power, and to use one of the forms of water-wheel hereafter described. But it happens that water-power is exposed to frequent interruptions, so to speak, in its efficiency; and that in summer, when the largest quantity of water must be raised, the power is the least, whilst in winter the action of the wheels may be entirely suspended in consequence of floods or of frost. In England, therefore, where coal is cheap, and the use of steam-power is habitual, the latter is almost always resorted to, and it certainly presents many advantages, on the score of certainty of action, over all other sources of motive power. In France, Germany, Switzerland, and the United States, however, many water-wheels for the supply of towns are to be found; and even within a very few years London itself was dependent for a large portion of its water supply upon the water-wheels of old London Bridge. The towns of Toulouse, Geneva, Richmond, Va., and Philadelphia, may be mentioned as amongst the most important of those supplied with water by water-power; and in the works lately executed by Mr. Hawksley, at Weymouth, a very ingenious application of the turbine was made. The majority of the English towns are supplied by means of steam-engines; and the machinery lately erected for the supply of London may be cited as being the most extensive and the most beautiful of any hitherto erected. It is usually considered that there are advantages in the use of the Cornish pumping-engines when the power to be exercised exceeds 25 horses, and that for lower powers direct-acting engines, or fly-wheel engines, are preferable; but the remarkable results obtained by Messrs. Simpson and Boulton and Watt, show that the preference for large Cornish engines is at least open to question.

In estimating the power to be provided, and consequently in deciding the description of engine to be employed, it is necessary to take into account the weight of the water to be raised at the maximum rate of consumption; the total height to which it has to be raised; and the various causes of retardation of flow in the pumping main, from the friction upon the sides of the pipes, and the bends or changes of horizontal or vertical direction. It will be necessary to revert to the general laws affecting the flow of water in pipes; but here it is sufficient to observe that an allowance equivalent to an increase of 12 feet per mile in length of main, to the total weight to be lifted, is sufficient to cover the effect of these retarding causes. As the various classes of engines do not work up to their full power, calculated theoretically, it is necessary to affect the result of the above method of ascertaining the pumping power by the coefficients of the respective engines; which are, for steam-power, on the average, 0·85, and for the best water-wheels, 0·75.

In small pumping engines it is found that the most useful action is obtained when the power is exercised equably and continuously; and in order to secure this result, the main shaft is made to carry three cranks placed at angles of 120° from each other, upon which the pump rods are keyed. In the larger engines it seems that the most favourable conditions of motion in the pumps are, that they should begin by raising the load rapidly, in order to overcome its vis inertia; and that when the motion of the ascensional column has been once established, the effort of the motive power should gradually be diminished. These objects are effected in the Cornish engines by introducing steam to the underside of the cylinders, through large openings, at high pressures; the steam is then cut off when the inertia of the water has been overcome, and it is allowed to expand during the remainder of the stroke, exercising in so expanding sufficient power to maintain the ascensional movement; the return stroke is made by the dead weight of the plunger and of the rods. The initial pressure of these engines is usually from $2\frac{1}{2}$ to 3 atmospheres; the expansion begins at from $\frac{1}{8}$ to $\frac{1}{4}$ of the stroke of the piston; and at the end of the stroke the pressure of steam is not more than between $\frac{2}{10}$ and $\frac{3}{10}$ of an atmosphere; engines so worked being said to produce a duty equivalent to about 90,000,000 lbs. raised 1 foot high by the combustion of 1 cwt. of coal. But it is to be observed, that in consequence of the interposition of the air-vessel upon the delivery-pipe of a town pumping-engine, the delivery is, in fact, constant; and it is probable that the extraordinary results obtained of late by the application of the beam and fly-wheel engine, on a large scale, to pumping operations, may be explained by the fact that as they supply water to the air-vessel in a more continuous manner than the Cornish engines do, they allow the air-vessel to produce its effect with greater regularity. In the large engines erected by Messrs. Simpson for the Chelsea and Lambeth Water-works, the steam works at high pressure in the first of two cylinders, and at low pressure in the second; there is a beam and fly-wheel to each engine; and it is said that the duty they perform sometimes reaches 120,000,000 lbs. raised one foot high by the combustion of 1 cwt. of coal. Fly-wheel engines, it may be added, possess this great advantage over Cornish engines for the purpose of town distributions, namely, that they are capable of being worked at more variable rates of delivery than are the latter; and in a town delivery the rate of consumption is subject to such singular irregularities, that this susceptibility of variation in the power may often be a matter of importance. But again, it must be stated that the best modern Cornish engines have been so carefully and skilfully constructed, that they have even allowed the regulating service reservoirs to be dispensed with; and both the Kent and the East London Water-works pump directly into their supply mains by night and by day, trusting entirely to the skill of the engine-drivers to adapt the motive power to the variable conditions of the consumption of their districts. These variable conditions are of much greater importance than is generally considered to be the case; for it appears from careful examination that about three-fourths of the total daily consumption of a town takes place between the hours of eight in the morning and eight in the evening; and experienced engineers make their pipes and engines large and powerful enough to discharge one-fourth of the total daily consumption in one hour. Evidently, then, it must be desirable to employ the motive power which is able to adapt itself to such variable demands with the greatest elasticity.

In passing from the pumping station to the regulating reservoir, or to the point of distribution, the water usually flows through a simple pipe of a uniform sectional area; and, as far as it is possible to secure that condition, with a uniform, constant velocity. In its course, however, the water is retarded by a series of resistances, which practically may be resolved into those depending upon :—1. The friction on the sides of the pipes; 2. The existence of bends, or changes of direction; and 3. The gurgitation which occurs at every interruption in the uniformity of the flow. The two former of these interfering causes act upon water flowing in open channels, and have therefore to be taken into account in fixing the dimensions of those channels; but the last named cause acts exclusively upon water flowing in pipes. In the following remarks upon the flow in pipes it must, however, always be understood that they are supposed to run full bore, and to have got perfectly "in train," to use a technical phrase; that is to say, it is supposed that a constant velocity is maintained in those portions of the pipes wherein there are no side branches.

Now, the friction on the sides of the pipes depends principally upon their diameters, and upon their lengths, and upon the pressures upon the respective orifices of supply and discharge; and as the latter conditions (the pressures) are in fact analogous to the effect of a column of water, or "a head," as it is commonly called, it is customary to reason upon the pressures in terms expressing the heights of such columns. Practically it appears that the results obtained by allowing for the above cited elements of the resistance produced by friction, require to be affected by a term depending upon the initial velocity of the water; and according to some recent investigations by M. Dupuit, by another term depending upon the material of the pipe. For ordinary purposes it is often not necessary to take these causes of diminished supply into account, and it then suffices to consider that the quantity of water flowing through a pipe of uniform diameter, receiving its water from a reservoir at a high level, and discharging it into another reservoir at a lower level, the pipe being without any change of direction, may be represented by the formula $Q = c\sqrt{\frac{H+\zeta-H'}{\lambda}}D^5$; in which Q = the quantity sought; ζ = the difference of level between the extreme orifices; λ = the length of the pipe; H = the initial head; H' = the head over the lower orifice; D = the diameter of the pipe; and c = a coefficient ascertained by experiment when the velocity of flow, per second, is as follows :—

Velocity.	2 inch.	4 inch.	8 inch.	12 inches.	20 inches.	78 inches.
$c=$	15·06	17·92	18·83	19·50	19·84	20·79

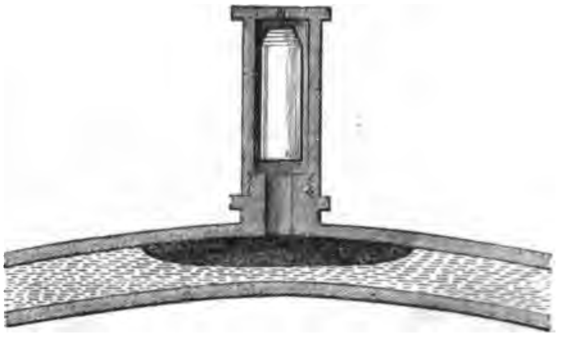
And for any velocity beyond 78 inches per second, $c = 21{\cdot}043$. But this formula can only be applied when the velocity is previously known; should this not be the case, or should it not be ascertainable by actual observation, it may be calculated by a second formula in which making $K = \frac{H+\zeta-H'}{\lambda}$ (the previous notation being retained), then, V, the velocity $= -0{\cdot}1541131 + \sqrt{0{\cdot}023751 + 32806{\cdot}6 \times \frac{DK}{4}}$. When it becomes necessary to take the friction on the sides of the pipe into account, it is ascertained by calling, firstly, the velocity due to the vertical head, without any allowance for friction, v, or expressing it in terms of the height $H = \frac{v^2}{2g}$, then $H - \frac{v^2}{2g}$ will be the portion of the head destroyed in producing that velocity, or the loss of head produced by the friction. Secondly, if we call the length of the pipe λ, the sectional area S, the wet contour C, and the two coefficients it is necessary to introduce respectively, a and b; the expression of the resistance would become $a\frac{C\lambda}{S}(v^2+bv)$; and we should have $H - \frac{v^2}{2g} = a\frac{C\lambda}{S}(v^2+bv)$. It is then only necessary to ascertain the value of the coefficients a, b, in order to apply the formula for general use; but unfortunately every observer has attached different values to them. In this state of uncertainty it is sufficient to adopt the formula and values attached to the coefficients by Weisbach, in his 'Treatise on Mechanics,' because the formula is simple, and is known to give safe results; that is to say, results which are rather in excess of those ascertained by direct experiment, but sufficiently accurate for practical purposes. Weisbach calls the loss of head h'; and confining his attention to the length and diameter of the pipes, he makes $h' = \left(0{\cdot}01482 + \frac{0{\cdot}017963}{\sqrt{v}}\right)\frac{l}{d} \cdot \frac{v^2}{2g}$; the result being in feet.

The friction, and the consequent loss of head, from the existence of bends, is found to be in a certain proportion dependent upon the ratio of the diameter of the tube to the radius of curvature of its axis. Navier says, that the formula $h_1 = \frac{v^2}{2g}\left(0{\cdot}0039\frac{1}{r} + 0{\cdot}0186\right)\frac{a}{r}$ (in which r = the radius of the curvature, and a = the development of the arc), will represent the loss of head thus occasioned; and according to him it would appear that h_1 is proportional to the square of the mean velocity, and to the length of the arc; that it is a function of the radius of the arc, and independent of the diameter of the pipes; and that h_1 decreases in proportion as r increases. In order to apply the above formula to the case of side mains branching off from a leading main, it is necessary to adopt the following ratios between the diameters and the radii:

Diameter.	2 to 3 in.	3 to 4 in.	6 inches.	8 inches.	10 in. and upwards.
Radius r .	1 ft. 6 in.	1 ft. 8 in.	2 ft. 6 in.	3 ft. 6 in.	5 feet.

The interference with the rate of delivery of a pipe by the gurgitation produced by the changes in the conditions of flow, may practically be neglected in the calculations for proportioning the details of a town distribution; because it is easy to effect the pumping in the leading main with sufficient regularity to avoid its serious occurrence, and to make the distributing mains large enough to destroy its influence. Attention has, however, been called to this interference on account of the lesson it affords of the danger of adhering too strictly to the dimensions of pipes which would appear to be indicated by abstract theoretical laws; and of the necessity which exists for providing for irregular disturbing causes. There is another danger to be encountered in the delivery of water through long leading mains, namely, the danger arising from the accumulation of air in the bends, especially when they are in a vertical direction, for the air then has a tendency to accumulate at the summit of the bend, and thus either to diminish the water way, or even to stop the passage of the water altogether. The remedy for this evil consists in the establishment of air-vessels upon the summit of the bends, through which the air may escape; and any slight retardation of flow created by the small quantity of air left in the water, or by the dead weight of the small column to be lifted, must be provided for by increasing the initial velocity of flow. In important works it is customary not only to introduce air-vessels, but also pressure regulators at the summit of the large bends, in order to ensure equality of flow. *Fig.* 1. represents a very simple air-valve which has been successfully applied.

Fig. 1.



The formulæ for calculating the discharge of pipes under certain fixed conditions of head and diameter, cease to be applicable when there is a series of branch-mains, sub-mains, and service-pipes attached to the leading main, such as always occurs beyond the service reservoirs, or the first point of distribution in a town supply. In fact the dimensions to be given to the distributing pipes can hardly be decided upon other than upon empirical principles, and long experience is a better guide in these matters than any abstract theory. The method adopted by Mr. Hawksley may perhaps be cited as the one most generally satisfactory, and it has been described by himself by saying, that upon the constant delivery system (in which the pipes are always under charge, and no cisterns are used), he divides the length of the main in a street into portions of about 200 yards each, and he assigns to every such portion the quantity of water it would be likely to require, in proportion to the population to be supplied by it, on the supposition that the total quantity is to be delivered within four hours. He then allows for a loss of head of 4 feet in every 200 yards; and adopts, in calculating the diameters to be given to the pipes, the formula $d = \frac{1}{15}\sqrt{\frac{q^2 l}{h}}$; in which q = the number of gallons to be delivered; l = the length of the main in yards; h = the head in feet; and d, the diameter required, in inches. In Claudel's 'Formules à l'usage des Ingénieurs,' there is to be found a description of a more elaborate and theoretically correct method of ascertaining the diameters of sub-mains; but it is so much more complicated than the one used by Mr. Hawksley, that it will suffice for the purposes of this Cyclopædia to refer the reader to the work in which it is explained.

In carrying into effect a town distribution it is necessary to observe numerous precautions, in order to protect the pipes from injury by external causes. Thus, wherever gas- and water-pipes are laid in proximity to one another, the water-pipes should be laid at a lower level than those conveying gas. In England it is sufficient to place the gas-pipes at about two feet from the surface of the pavement; but in order to protect the water-pipes from the effect of frost, it is necessary to place them at least 4 feet below the same level; and in the latitudes of Berlin, or of St. Petersburg, it has been found that water-pipes have been frozen at even 6 feet from the surface of the ground. In towns wherein the street traffic is exceptionally heavy the vibrations of the ground may also require that the pipes should be laid at a considerable depth, and indeed this detail may be considered to vary in almost every case. It would appear that when the pipes are laid at about 4 feet from the surface in our latitudes, the temperature of the water as it leaves the pipes will be sensibly the same, at all seasons of the year, with its temperature at the moment of entry, provided the motion be maintained in the pipes uniformly; and it thence follows that one of the best precautions which can be adopted against frost is to maintain a constant circulation in the pipes. The dilatation of the pipes from an increase of temperature must be taken into account in laying down any system of town distribution; and it would appear from M. Girard's direct experiments that the average rate of dilatation is equal to 0·00000300228 of a foot for every additional degree of Fahrenheit's scale, when the pipes are free, and in the open air. In the ground M. Girard found that the temperatures of the pipes were functions of the difference of temperatures of the surrounding media; but that they were nearer to the temperature of the ground than to that of the water. The tendency of some waters to produce deposits in the pipes they traverse must also be taken into account, as it may affect the discharge in a very serious manner; in some instances, in Yorkshire, the bores of the leading mains have been known to have been thus diminished in a few years to one half their sectional area by the deposition of the hydrous oxide of iron; in mains supplied directly from chalk or limestone springs the same effect may be produced by the deposition of the bicarbonate of lime. M. Payen states also that the slightly alkaline and aërated waters are those which are the most likely to produce a development of tubercules of the hydrous oxide of iron in the interior of pipes of that metal; and that the oxidation takes place more rapidly upon gray cast-iron than upon the whiter varieties. It appears from experiment, and from the results obtained in practice, that by coating the interior of water-pipes with a solution of hydraulic lime, or with linseed oil containing litharge, the formation of the tubercules before mentioned will be retarded; and in London the precaution of thus coating the pipes is universally adopted. The chloride of sodium when present in the water in small quantities, it may be added, facilitates the formation of the tubercules.

Until within a few years the distribution of water to the private consumers was effected by the intermittent system, or by means of a supply passed through the street-mains, at certain hours of the day, into cisterns placed in the houses, where it was stored for domestic use as might be required. The cisterns, in such cases, are made with float-valves, such as the common ball-cock, *fig.* 2, or the lever-valve, *fig.* 3, which close the delivery-pipes when the water attains definite levels: and, in addition to these means of stopping the supply when a sufficient quantity of water has been delivered, the cisterns are provided with an open overflow pipe connected with the drainage of the houses, through which the excess of water may pass, if the machinery for intercepting the flow should not act. It is found, however, that, in the first place, there is so much carelessness in the manner in which the cisterns are fixed and maintained in order, that the quality of the water is very liable to be contaminated in private houses. The great cisterns are, in fact, too often placed close to water-closets or sinks; the service-pipes to the water-closets often form a direct communication between the pans of the closets and the water in the cisterns, so that the gases from the one must escape through the other; the cisterns are too often made of improper materials; they are left exposed far too often to receive atmospheric impurities, dust, or soot; and, incredible as it may sound, it is very rarely indeed that cisterns are cleaned out from one year's end to another. The best water in the world so treated must be rendered more or less unfit for human consumption; and it was principally to avoid this evil that the constant-delivery system was introduced, avowedly because that system allowed the cisterns to be dispensed with altogether. But it was also asserted that the constant-delivery system would effect an economy in the supply of water, because it is found practically that in the lower class of dwellings the ball-cocks are either stolen or tied up, so that the excess of water was forcedly passed through the waste- or overflow-pipe during a great portion of the time the street mains were undercharged. Unfortunately the economy has not been attained; on the contrary, whenever the water supply of a town has remained in the hands of a municipality, it is found to be so difficult to maintain the necessary control and supervision over the distributory apparatus, that the waste upon the constant-delivery system has proved to be so enormous that the system has practically been abandoned in many cases. It really would appear that the only means by which the abuses of the otherwise perfect method of delivery under constant pressure could be prevented would be by enforcing the sale of water by meter; and, indeed, as water is nearly as valuable as gas, there can be no reason for selling the one by measure and not the other. Gas, in London, costs 4*s.* 6*d.* per 1000 cubic feet; water, at the rate of 6*d.* per 1000 gallons, costs 3*s.* 1·38*d.* per 1000 cubic feet. But hitherto no water-meter has been devised by means of which the water can be measured without intercepting the pressure; so that at present there appears to be an almost insuperable difficulty in the way of the introduction of the constant-delivery system in many towns about to construct water-works *de novo*. In towns like London, the difficulties which would attend the modifications of the existing domestic arrangements of the water-pipes would be so great, that it is to be feared the present evils of the intermittent system will continue to be borne for many years still to come.

Fig. 2.

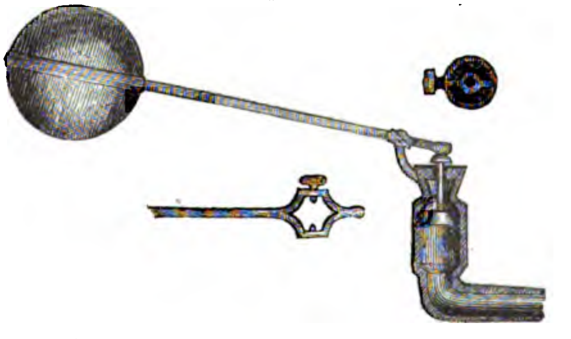
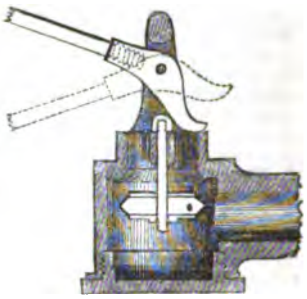


Fig. 3.



The water supplied to houses is, generally speaking, conducted from the street-mains to the cisterns, and thence distributed where required by means of leaden pipes, on account of the ease with which they can be bent, so as to accommodate themselves to the construction of the house. Some waters, however, especially those containing free carbonic acid gas in suspension, act upon the lead with remarkable energy; and instances of lead poisoning are by no means uncommon when the waters distributed are remarkably soft. When waters exposed to this danger must be used, it is necessary to employ either wrought-iron, or tin, or composition service-pipes; but these waters are far from being innocuous, even to these substitutes for the more flexible material, lead. The only other general remarks to be made with respect to house-distribution of water are: 1, that the apparatus for drawing the water should be of such a nature as not to produce a hydraulic jar on its being opened or closed; 2, that the pipes should not be placed so as to be exposed to the permeation of gases, or to the effects of heat or of frost; 3, that they should at all times be accessible for examination and repair. The thickness of service-pipes may be calculated upon the formula $x = \frac{pr}{c-r}$, in which x = the thickness sought, p = the pressure in lbs. per superficial inch, r = the radius or half the internal diameter of the pipe in inches, and c = the cohesive strength of the metal per superficial inch. Mr. Hawksley makes the thicknesses of his cast-iron pipes equal to $0{\cdot}18\sqrt{d}$, or about $\frac{1}{5}$ of the square root of the diameter. In practice, lead-pipes are made equal to $\frac{1}{15}d$ in small pipes, and to $\frac{1}{20}d$ in very large ones.

The quantities of water required for the various details of domestic distribution are as follows:—

A bath requires, each time it is used, about . .	75 gallons.
A horse requires, per day	16½ „
A two-wheeled private carriage, per day . . .	9 „
A four-wheeled „ „ . . .	17 „
Each individual in a house, „	4 to 8 „
A water-closet, every time it is used	1 gallon.
A yard superficial of garden ground	0·33 „
A yard superficial of roadway, every time it is watered	0·22 „

Generally speaking, the charge for a house supply is based upon its estimated rental, in England at least, and it very rarely attains 5 per cent. on that value. But an additional charge is made whenever more than one water-closet is in the house; when fixed baths are used; for coach-houses and stables, according to the number of carriages and horses; and for gardens. Such trades as tanners, fellmongers, hair-washers, curriers, glue-makers, dyers, hatters, brewers, distillers, manufacturers, inns, public baths, and steam-engines, are considered as large consumers, and are usually supplied with water by meter. The price under the latter arrangement is, in London, about 6*d.* per 1000 gallons. The supply of water for the extinction of fires is, in this country, cast upon water companies; and it appears that in the New River district of London there is at least one fire-plug in every length of sub-main equal to 73 yards, on the average; on the great mains there is a plug to every 157 yards. For the purpose of street-watering, stand-pipes ought to be placed at distances of about 500 yards apart: in our climate it appears that the streets require watering between 120 and 135 days in the course of the year, sometimes even twice in the day. The quantity of water varies with the nature of the road-surface; and where nicety of calculation is required, it may be considered that 600 square yards of macadamised road will only require one ton of water, whereas 400 square yards of paved road will require that quantity. It may be added, that the street-plugs (the *borne fontaines*) used in Paris to cleanse the channels are usually placed at distances of about 140 yards, and that they discharge at intervals during the day a total quantity of water equal to 650 gallons each: more than half the total supply of Paris is thus poured into the streets.

It would be idle to give any statistics of the capital invested in water-works, either in England or elsewhere, because new works of this description are being constantly undertaken. In London alone the capital invested in the various Water-Works Companies cannot be considered to be much less than eight millions sterling; and, as a general rule, it would appear that the average cost of conducting a water supply to the doors of the houses in a town varies between 2*l.* and 3*l.* per head of the population; whilst the house distribution gives rise to a further outlay varying from 4*l.* to 20*l.* per house, according to its character and to the system of distribution adopted. In newly-established works, the constant-delivery system admits of considerable economy in this respect. Of late years, also, it may be added that more attention has been paid than was formerly the case to the pressure under which water is delivered in towns; and that, to a great extent, the distinction between high and low service has ceased to exist. In new works the mains are always laid under such conditions of pressure upon the water they contain as to cause the latter to flow in the loftiest rooms of the loftiest houses in the respective towns.

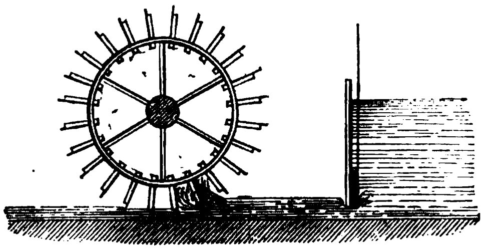
In Robison's 'Mechanical Philosophy,' in Playfair's 'Lectures,' in Jamieson's 'Mechanics of Fluids,' Weisbach's 'Mechanics of Machinery and Engineering,' D'Aubuisson's 'Hydraulique,' Geniey's 'Essai sur les Moyens de conduire et élever les Eaux,' Darcy, 'Sur les Fontaines Publiques de la ville de Dijon,' Dupuit's 'Essai sur la conduite et la distribution des Eaux,' and dispersed throughout the various Blue-Books and Parliamentary Evidence upon the subject of town water supplies, much information upon the practical details of that branch of the municipal service is to be found. Unfortunately, there is no work in English, treating this subject exclusively, which can be considered to be of any value; and the reader cannot be too seriously warned against accepting, absolutely, any of the doctrines lately promulgated here "by authority." The French writers upon hydraulics are still those who are to be the most implicitly followed in matters of theory; the practice of the best English engineers in matters of working detail must be consulted, in spite of the official censure passed by a class of empirics who seem to have objected to eminent engineers solely because they were eminent. Dwyer's 'Hydraulic Engineering,' Neville's 'Hydraulic Formulæ,' Downing's 'Practical Hydraulics,' and Beardmore's 'Hydraulic Tables,' may also be consulted with advantage.

WATER-WHEELS. The machines, by means of which the weight, or the impulse of water, is converted into circular, vertical, or horizontal motion, are known in mechanics by the name of *water-wheels;* and as the power thus employed is furnished by nature, and requires but little outlay to be rendered available, these machines have at all times attracted much attention from the manufacturing interests. They are of various descriptions, according to the conditions under which the waters flow, or the uses to which the power thus converted is to be applied; but they are all alike in this respect, namely, that the motion they receive is always circular, whereas in the other modifications of water-power, the motion is rectilineal, and alternate. Water-wheels are in fact subdivided into those with floats or blades; and those with buckets. The wheels with floats are divided into the classes which have either straight or curved floats; and into those working in free water, in races, or water troughs either straight or curved. The bucket-wheels may be adapted to receive the water at the summit, or at an intermediate point of their height; but the float-wheels are exclusively of the kind known as the *undershot-wheels,* whilst the bucket-wheels are either *overshot-* or *breast-wheels;* the latter distinctions depending upon the height at which the water strikes the wheel, for in the *undershot-wheels* the water acts below the horizontal line passing through the centre of the wheel: in the *overshot-wheel* it acts above the said horizontal line, and on the downside (to the current) of the vertical line passing through the centre: and in the *breast-wheel* the water acts at a variable angle above the horizontal line through the centre, but on the same side as the stream flows naturally. In addition to these are the horizontal wheels, which are either set in motion by an isolated vein of water, or are placed in a cylinder, or are placed around a cylinder conducting the water, in the manners already described under TURBINES. Sometimes a modification of the overshot-wheel is used, under the name of the *backshot-wheel,* in which the water is carried beyond the summit, and thence returns to strike the wheel at a point situated a little below that level, on the upper side of the vertical line passing through the centre of the wheel.

The parts of a water-wheel and its adjuncts which it may be desirable to define, are as follows. In the water channel there is, generally speaking, a *mill-head,* with tumbling bay and waste weir to regulate the supply of water to the *fore-bay,* or the channel leading the water directly upon the wheel; this fore-bay has a *hatch,* or sluice, by means of which the quantity of water falling upon the wheel can be regulated at will. The *mill-race* is the part of the channel immediately under the wheel; the *tail-bay* is the part by which the water escapes after it has produced its effect. The wheel consists of a *shaft,* upon which are fastened the *arms,* bearing in their turn the *periphery,* to which are attached the *floats* or the *buckets;* sometimes this periphery is close boarded, or *soled,* sometimes it has openings for the purpose of ventilating the buckets; the sides of the buckets which keep the water upon the wheel are called the *shrouds.* The motion is taken off from the wheel either by gearing working upon the segments of the wheel, or by first motion, or bevilled wheels fixed upon the axle; the last are generally known by the name of *pit-wheels.*

Formerly the vertical wheel, with straight floats working in a straight mill-race, was the description of undershot-wheel most generally adopted, but it is now seldom used, unless in cases where there is an abundance of water, and a fall not exceeding five feet (*fig.* 1.) In these wheels, the water acts entirely by its shock, and evidently this must be proportionate to the velocity with which it issues from the hatch, under the pressure of the head in the fore-bay. The distance between the hatch and the wheel must therefore be made as small as possible, because the water in spreading out in the mill-race is exposed to lose a portion of its velocity. The fore-bay should be made with converging sides, upon the principle of ordinary conical ajutages, wider towards the dam than to the sluice; and from Poncelet's experiments, it would appear that a great increase of useful effect is obtained by making the hatches incline, so as to offer an angle, towards the dam, of 45°. Immediately beyond the centre line of the wheel, the race must fall away, so as to leave a more uninterrupted discharge into the mill tail; its width must be regulated by the quantity of water to be discharged, because it is found practically that the depth of the stream ought not to exceed 10 inches when the course is clear; the depth also should never be less than 6 inches, and in order to lose as little of the water as possible, the space between the outer edge of the wheel and the mill floor, should not be more than ½ or ¾ of an inch. In the most carefully constructed mills at the present day, a great improvement in the efficiency of the wheels is obtained by giving an inclination to the floor of the race from the hatch, to the level of the lower edge of the second float on the upside of the vertical diameter, of about 1 in 12, or 1 in 15; the bottom then curves away from that point, concentrically to the wheel, until it meets the vertical diameter line prolonged; and it then falls away with a sudden drop of 4 inches, and every precaution is taken to ensure the rapid withdrawal of the tail-water. The width of the race is made somewhat smaller than that of the floats until a short distance before the position of the wheel; and beyond the centre line it widens out still more than the width of the floats.

Fig. 1.



As the water, on escaping from the hatch, heaps up against the float, the latter must be made deeper than the normal thickness of the fluid vein; and generally speaking this is effected by making the floats about three times the depth of the water in the race, provided the width does not exceed 2 feet, or 2 feet 2 inches. The distance from one float to another should be rather less than the depths of the floats, their number being regulated principally by the purposes to which the machinery is to be applied. The diameter of the wheel is fixed in most cases by the number of revolutions it may be required to perform in a given time, in order to drive the connected machinery at the desired speed, and with the intervention of the smallest number of parts; and to a certain extent it is desirable to make the wheel act as a fly-wheel, to regulate the movement of the machinery. In the best wheels, the velocity of the extremity of the floats is made $v = 1{\cdot}7\sqrt{\text{H}}$, in which v = the velocity, and H = the fall of water; and the diameter is made $\text{D} = \frac{32}{\text{N}}\sqrt{\text{H}}$, in which N = the number of revolutions per minute; and D = the diameter sought: it is rarely, however, that the diameter of undershot-wheels varies beyond the respective limits of 13 and 26 feet. The numbers of floats usually adopted are, for the diameters given, as follows: they are multiples of four, because millwrights prefer distributing them equally upon the quadrants of the wheel; but it is to be understood that the number may be increased without inconvenience, if such a course were desired.

Diameter.	13 ft. 6 in.	16 ft. 6 in.	20 feet.	23 feet.	26 feet.
No. of floats .	28	32	36	40	44

It is found theoretically that an undershot water-wheel, in which the water thus acts by its shock upon floats working in a straight mill-race, only yields an efficient power equal to half the dynamical effort exerted upon it, even under the most favourable circumstances. But in practice, Smeaton's experiments appear to show that the useful results rarely attain even that value; and that calling the weight of water P, and the height of the fall H, the real effect does not exceed 0·25P H. The useful effect of these wheels is, therefore, very small; but the facility they present for variations in the diameters of the wheels, and in their velocities, renders them at times advantageous, when an unlimited supply of water is at hand.

In the previous remarks it was observed, that the useful effect of the undershot-wheel was improved by making the race concentric to the outer circumference of the wheel. The gain thus secured is proportionate to the arc enclosed; and the practice at the present day is, therefore, to make that arc as large as the fall will allow (*fig.* 2), and usually it is made equal to ⅔ or ¾ of the available fall. A space of about half an inch is left between the circumference of the wheel and the surface of the enclosing arc of the race; the width of the stream is made such as to allow it to fall on the wheel with a thickness of about 8 inches, and the diameter and number of the floats are calculated as before. The useful effect of these wheels is said to range between 0·60 and 0·65P H. M. Poncelet has, however, increased still more the useful effect of the undershot-wheels by making the floats curved, as shown in *figs.* 3 and 4, and by doubling their number. He confines the water within a close race, and takes more than ordinary precautions to remove the tail-water; he makes the depth of the floats vary between ¼ and ½ of the vertical fall in the inverse proportion to the height of the latter. But with all these improvements, it seems to be very difficult to secure from the best undershot-wheels a greater useful effect than is represented by 0·60 P H.

Fig. 2.

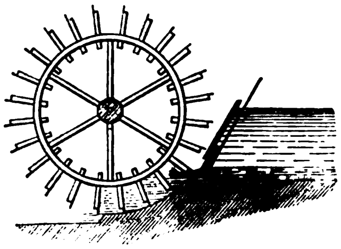


Fig. 3.

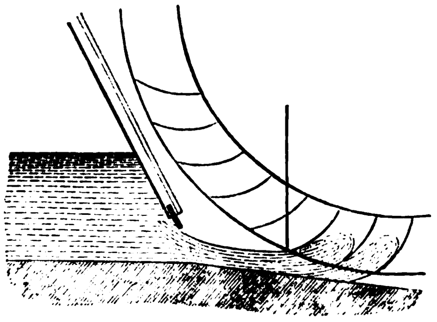
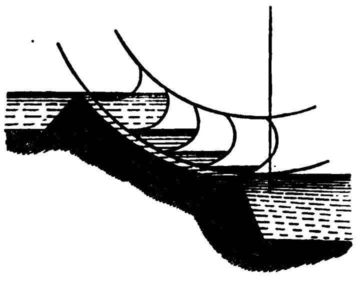


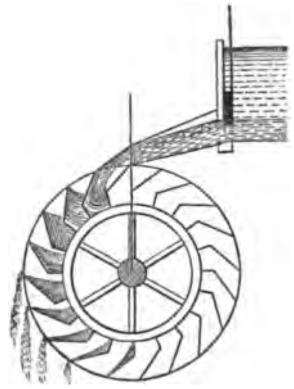
Fig. 4.



A species of undershot-wheel is sometimes used upon rivers, which consists of a vertical float-wheel worked by the current of the river, or even occasionally by the tide. The diameters of these wheels are rarely of considerable dimensions, and the proportion of the useful effect to the power actually exerted is but small; nevertheless, these wheels are extremely useful in new countries, and they present one great advantage from the fact of their not interfering in any way with the natural drainage conditions of a locality, as the other classes of mills with heads and dams almost inevitably do, from their upholding the water. [TIDAL WHEEL.]

The vertical *overshot-wheels* with buckets, *fig.* 5, are those in which the water is carried over the top of the wheel, and then made to strike the buckets upon the side of the mill-tail, so that the descent of the wheel is caused by the weight of the water on the unbalanced side; the shock of the falling water adding slightly to the motive power. As in ordinary undershot-wheels, the overshot ones consist of the axle, arms, rim, shrouds, sole, and buckets; which may be of wood or of iron, according to the resources of the locality where the mill is to be erected; the advantage in the use of iron consisting in the facility with which the buckets can be worked to the best theoretical outline, and in its durability; the advantage of wood consisting in its primary economy, and its facility of repair.

Fig. 5.



The number of buckets on an overshot water-wheel is determined upon the following scale, which is found practically to be the most successful, namely, the diameters being given, the number becomes—

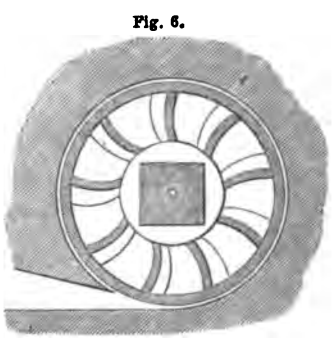
Diameter.	10 ft.	13 ft. 6 in.	16 ft. 6 in.	20 ft.	26 ft.	33 ft.	40 ft.
No. of buckets	24	36	44	56	76	96	108

That is to say, assuming the depth of the shrouds to be, as it usually is, 12 inches, and drawing a circle at one-third of that depth, measuring from the inside, the buckets are spaced upon that circle at distances apart of 13 inches, as nearly as may be. The length between the shrouds will be determined by the quantity of water they have to deliver; and it is desirable not only to make the capacity of the buckets sufficient to receive all the water which may pass into them from the hatch, but also to make their capacity equal to three times that volume, or the water would have a tendency to splash over, and to escape. Generally speaking, the water is carried over the top of the wheel, at a slight distance from it, and is made to strike the second or third bucket beyond the summit, at about 2 feet from the vertical line passing through the centre; because it is considered that the shock thus obtained increases the dynamical force of the water. A more important precaution still than either of those named above, consists in the provision of means of escape for the air contained originally in the bucket, or carried down by the falling water; and one of the greatest improvements effected of late years in the construction of overshot water-wheels consisted in the introduction by Mr. Fairbairn of the ventilating buckets. The diameter of the wheel, of course, should be made as nearly as possible equal to the height of the fall, and the velocity of the wheel kept to about the rate of 3 feet per second, measured on the outer edge. A greater velocity would produce a centrifugal force in the water contained in the buckets, which would to some extent diminish the useful effect of the wheel. The best overshot-wheels, in which the water is conducted upon the wheel carefully, and the tail-bay of the channel built so as not to interfere with the escape of the water, yield an effective result of 0·75 PH; and they are, therefore, constantly used when a sufficient fall can be obtained for their establishment. In some mining districts overshot-wheels of as little as 8 feet in diameter are used; but they do not yield even so good results as the best breast-wheels in close races. A fall of 16 feet seems, in fact, to be about the minimum fall able to produce the full amount of dynamical force an overshot-wheel is able to yield. As to the *backshot-wheels*, they do not involve any other principle than the overshot-wheels; nor, indeed, can they be considered to offer any advantage over the latter, unless in some peculiar cases, wherein the motion of the machinery may require the revolution of the wheel to take place in one particular direction; and wherein the water is required to be brought upon the back part of the wheel. Sometimes, it may also be added, there may be an advantage gained by the use of the backshot-wheel, if the tail-bay should be exposed to be flooded, or to receive backwater; because in such a case the revolution of the wheel would still be in the direction of the natural current, and the backwater would not oppose the passage of the buckets so seriously as would be the case with a true overshot-wheel.

The *breast-wheels* are those in which the water strikes the wheel on the upside, at a point intermediate between the vertical and the horizontal lines passing through its centre; and they are made with buckets of analogous forms to those of overshot-wheels, in order to retain the load on the side receiving the water as long as possible, and having the same provisions for relieving the air, and for obviating the effects of the centrifugal force of the water. In small wheels the water strikes the buckets at an angle of about 40° from the vertical line; in large ones the angle may be 30°, although some constructors make it as much as 52° for wheels of 20 or 30 feet in diameter. Evidently, however, the efficiency of a breast-wheel must depend upon the length of time it can retain the water on the loaded side, and the higher the point of impact, the greater must be the effect; in other words, a wheel receiving the water only a little above the centre line, the loaded arc becomes so small as to produce very trifling results. If then the fall should not exceed 8 feet, it would be preferable to adopt an undershot-wheel working in a close race, rather than a breast-wheel; because it would allow the application of a larger first-motion wheel. With a good fall, and with well proportioned buckets, the useful effect of the breast-wheel is often as high as 0·70 PH.

In some parts of southern Europe, where skilled labour is not easily obtained, and the work required to be performed is of a very simple nature, a number of water-mills exist in which the wheel, instead of being placed vertically, is placed horizontally, and the mill-stones for corn or oil grinding are keyed at once upon the vertical shaft of the mill. Some of these machines have a series of blades so placed upon the shaft, and with respect to the vein of water striking them, (and it is generally the case that the water is conducted for this purpose in a pipe,) that the shock takes effect normally to the plane of the blades. The corn-mills of the Saracens were made in this manner, and the peasants of Galicia retain them to the present day; but the efficiency of these rude machines depends entirely upon the height of the fall disposable, and the useful result obtained is rarely as much as 0·15 PH; so that these mills are never seen in highly civilised districts. On the banks of the Garonne, Tarne, Lot, &c., numerous mills, such as those represented in *fig.* 6, are to be seen.

Fig. 6.



The wheels are usually 3 feet 4 inches in diameter, and 10 inches deep placed at the bottom of a cylinder about 7 feet 6 inches deep, and 3 feet 4¾ inches in diameter. A channel gradually diminishing in width, as shown, admits water at the side of the cylinder above the wheel, and the water escaping from the sluice with violence acquires, in its course round the cylinder, a centrifugal force which acts against the curved blades not only by its impulse, but by its weight. There are many localities where wheels of this description would be of value; but even when the wheels are made of the best form, the useful effect they produce does not exceed 0·25 PH, and it is very rarely that they attain more than 0·16 PH.

The *reaction-wheels* are those in which the water is allowed to escape through apertures upon a vertical shaft, in such a manner as to develope a force in the reverse direction of the outflow, which is capable of being converted into a movement of rotation. Barker's mill, those designed by de la Cour, and by d'Ector, were based upon this principle; but the useful results they have produced have not been such as to lead to their practical application. They are in fact little better than philosophical toys.

It may finally be stated that in the present state of the arts of construction, the undershot-wheels with straight floats working in a close race are those which are the most adapted to falls of between 4 feet, and 8 feet 6 inches; the undershot-wheels with curved floats are the most advantageous when the fall does not exceed 5 feet. Bucket-wheels are desirable when the fall exceeds 10 feet, and is less than 16 feet; and when the supply is variable, it is preferable to use the breast-wheel rather than the overshot one: the breast-wheels at all times suffer less from backwater than any other form of wheel. Overshot-wheels are generally used when the fall ranges between 16 and 40 feet; above the latter fall there are decided advantages in the use of the turbine, which certainly has a remarkable power of adaptation to varying conditions. M. Fourneyron executed one turbine with a head of 9 inches, and another with a head of not less than 354 feet. Mr. G. Rennie states that the coefficients of the useful effects of the various descriptions of wheels are found in practice to differ slightly from those quoted above; and that they cannot with safety be taken at more than, in overshot-wheels, from 0·60 to 0·80; in breast-wheels from 0·45 to 0·50; and in undershot-wheels from 0·27 to 0·30.

(Smeaton, *On the Power of Mills*; Banks, *Treatise on Mills*; Buchanan, *Practical Treatise on Mill Work*; papers by Fairbairn, Glynn, &c.; d'Aubuisson, *Traité d'Hydraulique*; Morin, *Leçons de Mécanique Pratique*; Belidor, Euler, Navier, Bossut, Coriolis, &c.; *Repertory of Arts*; *Transactions of the Franklin Institution*, &c., &c.)

WATERING, in Horticulture, the process of applying water artificially to plants. Water in a greater or less quantity is necessary to the existence of the whole vegetable kingdom: not only do the elements of water enter into the composition of the tissues of plants, but by its agency the various saline ingredients, as well as certain gases that enter into the composition of vegetable tissues, are carried into the plant. Water also exerts an influence on the temperature of the soil and of the plants to which it is applied. It is on these accounts that the application of water to plants is an important process in horticulture, more especially in the hothouse and greenhouse. During winter plants require little moisture, as the processes of life are at that period very inactive, but at the same time a small quantity is required in order to meet the demands of approaching activity. If plants are supplied with too much water during winter, their tissues become distended, and the whole plant is enfeebled. The largest supply of water is required when plants are growing rapidly and at the season when they are putting forth their leaves. When plants have ceased to grow, or when the leaves and flowers have ceased to expand, they require less water. When however the object in the culture of plants is to render either their leaves or fruits as succulent as possible, they should be supplied with abundance of water. This is done with spinach, lettuce, and other oleraceous plants, and by this means their tissues are rendered more tender, and their peculiar secretions, which are often disagreeable, are diluted. The same thing is done in the cultivation of the strawberry, where the object is to render the fruit as large as possible. In this case however the large size of the fruit is obtained at the expense of its flavour. Even plants bearing succulent fruits, as the melon, &c., may be over-watered, and the flavour of their fruit destroyed. In supplying water to all plants due regard should be had to temperature, as, *cæteris paribus*, plants require more water in proportion as the temperature is higher.

Although the supply of water artificially to plants cultivated in houses is obviously necessary, there is some doubt as to whether it is required by plants growing in the open air, where they are exposed to natural supplies. Professor Lindley, in his 'Theory of Horticulture,' says, "It is indeed doubtful whether watering plants in the open air is not often more productive of disadvantage than of real service to plants." At the same time the practice is at present very general, and there are some advantages in it, independent of supplying plants with water. It is frequently very effectual for removing insects from the leaves of plants, and also for removing dust and dirt in exposed situations. Mildew is also prevented in annuals by abundant watering. The fungi which produce or are found on mildewed peas, and those which destroy the spinach and onion, may be removed by abundant watering. Where the leaves of plants are watered, this should never be done whilst the sun is shining upon them, as this increases the evaporation. The morning and evening are the best times for watering plants; but where it is necessary to do this in the middle of the day, the roots alone should be watered. After transplanting, whether of young or old plants, in pots or in the open ground, the watering of the plant is always recommended.

In watering plants several instruments are made use of, as the engine, the syringe, and the watering-pot. These are made either to throw water through tubes of various sizes so as to apply the water to a particular point, or by means of a rose which is appended to the tube to distribute the water over a larger surface. The former method is adopted when the roots of a plant are to be watered, and the latter when it is wished to wet the whole surface. Where a stream can be made use of, an effectual way of watering plants is to have a sluice by which the water of the stream may be let on and off as may be thought proper. This is the best mode of watering water-cresses and other plants requiring abundant moisture. Where there are water-works, pipes are sometimes laid for supplying compartments of a garden. Lawns and plots of grass may be watered from the water-butt.

WATERING OF LAND. [IRRIGATION.]

WATERMAN, one who rows a boat on a river for the conveyance of passengers. The only large body of watermen in England are those employed on the river Thames at London. Before the introduction of coaches they were a very essential class for the conveyance of persons not only between London and Southwark, but between London and Westminster, and up and down the river to the various places on each side. The Thames was then the great highway. Stairs and watergates were numerous on the north bank from London to Westminster, where there were many palaces of the nobility, each palace having its landing-place, its barges and wherries, and its private retinue of watermen, or bargemen, as they were then commonly called. Processions on the river, water-tournaments, boat-races, and other aquatic amusements were frequent. In the reign of Richard II. the fare for a passenger, with his truss or farthell, from London to Gravesend or Milton, was 2*d*. Stow computes that there were as many as 2000 boats in his time, that there were 40,000 watermen on the rolls of the Watermen's Company, and that they could furnish 20,000 men for the fleet. No doubt he included in this large number the private watermen of the court and the nobility. John Taylor, the "water-poet," as he styled himself, complains bitterly of the introduction of coaches: "I do not inveigh against any coaches that belong to persons of worth or quality, but only against the caterpillar swarm of hirelings. They have undone my poor trade whereof I am a member." Since that time the increase in the number of bridges and the introduction of steam-boats has reduced the watermen to a comparatively small number.

An apprenticeship of seven years on the Thames constitutes a free waterman. The watermen and lightermen are an incorporated company, founded in 1556, and regulated partly by their own bye-laws and partly by 7 & 8 Geo. IV., c. 75. With the exception of certain flat-bottomed ferry-boats and barges above Kingston, no person can ply in a boat for hire on the Thames who is not a member of the Watermen's Company.

The Trinity House has, however, power to license certain king's seamen, besides pilots, to ply on the river.

WATERS, MINERAL. [AERATED WATERS.]

WAVE. [WAVES AND TIDES.]

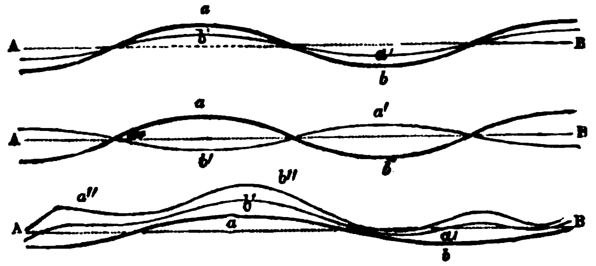
WAVES and TIDES possessing in many respects the same character, it has been thought proper to state in one article the phenomena and the theories of both.

From the earliest times the periodical risings and fallings of the waters on coasts or in rivers have been noticed; and the recurrences of the phenomena depend so obviously on the positions of the moon and sun, that the influences of those celestial bodies in producing them have ever been assigned as their cause. The tide appears as a general wave of water which gradually elevates itself to a certain height, then as gradually sinks till its surface is about as much below the medium level as it was before above it: from that time the wave again begins to rise; and this reciprocating movement of the waters continues constantly, with certain variations in the height (with respect to the mean level), and in the times of attaining the maxima of elevation and depression.

Ordinary waves are produced by any cause which disturbs the equilibrium of the particles of a fluid. Thus, a stone suffered to fall into water at rest gives rise to a series of concentric circular waves extending to a great distance from the place where the stone falls; and in a canal the fall of a body of water from a level above that of the general surface will produce a series of waves advancing along the canal. Waves are also produced by suddenly pressing a solid into water, or by suddenly withdrawing it from thence; and a single wave may be caused by partly immersing a solid body in water and moving it quickly, for a time, in a horizontal direction. The inequalities of the pressure of the air on the surface of water, whether at rest or in motion, when a gentle wind is blowing, will produce ripples; and if the action be continued long, the ripples, at a certain distance from the place of their origin, become considerable waves. In the open seas the heights of the waves depend on the force of the wind; but in confined situations both the heights and forms of the waves are affected by the resistance of the bed, by reflections from the shores, and other circumstances. When waves are formed by wind blowing from the land, each wave-summit preserves constantly the same height; but the heights go on increasing with the distance from the shore.

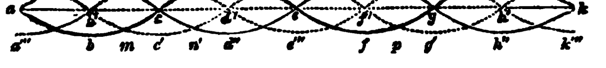
Wind-waves appear generally to be of a cycloidal form: their summits have a gentle curvature, while the height bears a small proportion to the length in the direction of the motion; but as the height increases, the summit becomes more acute, and assumes the form of a ridge; and when this becomes too sharp for the preservation of equilibrium, the force of the wind acting horizontally near the top breaks it into foam or spray [col. 783 of the present article. The nature of this spray itself has been noticed in WATERFALLS.] As waves advance towards a shore, the water becoming less deep, the resistance of the bed of the sea causes their lengths to diminish, and at the same time their heights to increase, so that the front of the wave becomes steep; and the motion of the upper part, towards the land, being more rapid than that of the lower part, it follows that the summit is carried beyond the base; and, falling forward, there is produced what is called a surf. The breaking of waves over a sunk shoal depends chiefly on a like cause.

The surface of the sea often presents very complex phenomena. It may happen, for example, that while a long swell resulting from some distant storm is advancing in one direction, a breeze will produce a series of waves moving in the direction of the wind; and a second breeze springing up in another direction will produce a new series, which will become mixed with the former without destroying them. a third gale may also produce a system of waves intersecting the other systems. When a breeze has been blowing for some time from a certain quarter, and afterwards changes to the opposite, two series of waves may be seen moving in contrary directions; and if the waves are nearly of equal lengths, the vertical ordinates at the crest of the compound wave will be equal to the sum or difference of the ordinates of the simple waves, according as the crests are coincident, or fall in each other's intervals. These phenomena are indicated in the first and second of the subjoined figures, where *a b* represents the first undulation and *a′ b′* the second, the straight line A B being the horizontal surface of the water when at rest. Again, when there exists a third system of waves, caused, for example, by reflection from a coast, so as to be parallel to the two former systems, the combination of the three systems has been observed to produce a compound wave of the form represented in the third figure. ('Report of the Committee of the British Association on Waves.')



The wind-waves of the sea do not extend to considerable depths. From the experiments made by the committee appointed by the British Association in 1836, it was found that with a depth of water equal to 12 feet, waves 9 inches high and 4 or 5 feet long did not sensibly affect the water at the bottom. Waves from 30 to 40 feet long, oscillating at intervals of 6 or 8 seconds, produced some effect, but much less than near the surface: and it was ascertained that, in waves produced by the wind on the surface of a deep sea, the velocities were not a direct function of the depth. In a storm the sea is probably tranquil at the depth of 200 or 300 yards. The most satisfactory measurements, those of the late Rev. Dr. Scoresby ('Report of British Association,' 1850, 'Journal of a Voyage to Australia'), give, for the height of the highest waves, 43 feet, from bottom of trough to crest.

It must not be imagined that when water is agitated by waves, its whole mass has the movement which at first sight appears from the observed progressive motion of the undulation; and, in order to account for the formation and motion of waves, it is sufficient to assume that the particles of water, when disturbed, have merely small oscillatory motions in horizontal and vertical directions. When, from any cause, as the fall of a stone into it, the water becomes agitated, a series of horizontal motions to and fro are produced; and while in a slender vertical column of water these motions are equal and in one direction, the surface neither rises nor falls; but if, in two neighbouring columns, the particles advance to meet each other, the water becoming compressed, the surface rises; if the particles recede from one another, those above descending by gravity, the surface falls. These different horizontal movements existing successively in the same vertical column, and simultaneously in those which are adjacent to each other, the surface of the water becomes undulated. In order, however, to understand the true movements of waves, let the straight line *a k* represent the surface of water when undisturbed, and, disregarding the hori-



zontal oscillations by which the water is alternately compressed and dilated, let the particles be conceived to ascend and descend alternately in vertical lines, that is, in lines parallel to $a'\,a\,a'''$, which is supposed to be perpendicular to $a\,k$. Now, at a given instant let the surface of the water have, in a vertical plane, the form $a\,b\,c\,d$, &c., and let the force of ascent cause the particles in the line $a\,b\,m$ to be raised up to the line $a'\,b'\,m$ in a portion of time represented by T, that force becoming less as it is farther from a horizontally, and ceasing at m. At this place the force of descent commencing, the particles in the line $m\,c\,d\,n$ fall simultaneously with the rise of the particles in $a\,b\,m$, and at the end of the same time T, they occupy the line $m\,c'\,d'\,n$. Here the force of ascent acts, and the particles in $n\,e\,f\,p$ at the end of the same time occupy the line $ne'f'p$, and so on. Thus at the end of the time T the surface of the water has assumed the form $a'b'c'd'$, &c. After this time the force of descent on the particles in the line $a'm'$ causes those particles to fall vertically, during a time equal to T, into the line am'; at m' that force ceases, and the force of ascent raises the particles in $m'b'c'n'$ vertically into the line $m'b''cn'$, and so on; thus, at the end of the time $2T$ from the given instant the surface of the water has the form $ab''cd''$, &c. In like manner, at the end of the time $3T$ the forces of descent and ascent will have brought the particles into the line $a'''b'c''d'$, &c.; and at the end of the time $4T$ the particles will be again in the line $abcd$, &c.: so that in this time every particle of fluid has made one complete vibration vertically, as $aa'aa'''a$, and within the same time the top of the wave has assumed successively the positions d, e', f'', g'', h. The horizontal distance from d to h is called the length of a wave; let it be represented by L, and let τ express the time $4T$ in which the summit of a wave has passed from d to h; then $\frac{L}{\tau}$ is called the velocity of the wave. On observing the characters of experimental waves in troughs with glass sides, it is found that, by the combinations of the horizontal and vertical vibrations, the particles of water describe the peripheries of circles or ellipses. In the upper parts of the curves, near the tops of the waves, the particles move with their greatest velocities in the direction in which the wave is advancing; in the lower parts, near the bottoms of the waves, they are moving with their greatest velocities backwards; and at the extremities of the horizontal diameters, about the level of the water's surface when at rest, the motion is almost wholly vertical.

The varying attraction of the sun or moon on the particles of water in the ocean is alone sufficient to produce the perturbations by which waves are formed; and if it be assumed that the solid nucleus of the earth is covered entirely with water, both nucleus and water being originally spherical, those perturbations will bring the surface of the water to a spheroidal form, the longer axis being in the direction of a line joining the centres of the earth and luminary; there will consequently exist, at the same instant, two great waves whose summits are at a distance from one another equal to half the circumference of the earth. But the motion of the water in the tide-wave is totally unlike that in an ordinary surface-wave such as the wind produces; and while the latter, even in the most violent storms, agitates the sea to a very trifling depth, the tide-wave affects the whole depth of the ocean equally, from the bottom to the surface.

Very little attention to the phenomena of the tides suffices to show that, in situations where the recurrences of high-water are nearly regular, the greatest elevation of the water takes place at intervals of about 12 hours 25 minutes, and the greatest depressions at the like intervals of time from each other; each greatest depression taking place about 6 hours 12 minutes after the instant of greatest elevation. Now the interval between two successive culminations of the moon on the same side of the geographical meridian of any place varies from about 24 hours 40 minutes to 25 hours; and thus the intervals between the times of high-tide have evidently a connection with the diurnal revolution of the moon; moreover, the occurrence of high-water at any place is observed to have a dependence on the position of the moon with respect to the meridian of the place; at a few ports it coincides with the time that the moon is on meridian, but in general it takes place some time before or after the culmination. The position of the moon at the time is, however, subject to certain variations even at the same port; and it differs considerably at different places. The elevations also of the water with respect to the mean level differ; in some places, during about half the year, the high-tide which occurs when the moon is above the horizon is greater than that which occurs when the moon is below, and during the other half-year the phenomenon is reversed. In every place, at about the times of new and full moon, the high-tides attain their greatest elevation; and at about the times of the quadratures, the least: the former are called *spring-tides*, and the latter *neap-tides*.

In bays and harbours, the time of high-water coincides with that at which the current ceases to flow, but this is not the case with the seas which communicate at both extremities with the ocean. For, if it be imagined that a tide-wave flows in at one of the extremities, this will cause an elevation of the waters; but the waters which are passing off at the opposite extremity cause, at the same time, a depression, or, at least, a diminution of that elevation; the surface, therefore, must be the highest when the current flows with equal rapidity at both extremities, and not at the moment preceding the turn of the tide. When the stream continues to flow up for three hours after it is high-water, it is said to make tide and half-tide; if it continues to flow during one hour and a half, it is said to make tide and quarter-tide, and so on. Near the shores of the British Channel, probably in consequence of the obstructions caused by the land, or the disturbances at the mouths of rivers, the progressive movement of the tide-wave is more retarded than in the middle; and in some places the current has curvilinear motions, which on the French and English sides are in opposite directions. The *race* of Portland is a current produced by the tide-wave, while advancing along the shore; being arrested by the promontory till it attains a height which allows it to flow off obliquely with considerable velocity.

The rise of a tide-wave near the mouth of a river takes place rapidly by the shoaling of the sea and the confinement of the wave between the banks; for the motion of a body of water is capable of raising the particles to the heights through which they must fall to acquire their actual velocities; and if the same motion is employed in raising a smaller quantity of water, it is evidently capable of raising it higher: thus, when the contraction is considerable, as in the Bay of Fundy, the Bristol Channel, and other places, the elevation becomes very great; at Chepstow it amounts to 60 feet. When, at the mouth of a river, the bed has a long and gentle slope on each side, the waves, becoming high and steep, fall over, and flow up rapidly with a surf, constituting what is called a *bore:* the bore-wave which enters the Severn is 9 feet high, and that which occurs in the Amazonas is said to be from 12 to 15 feet in height. [BORE, and col. 784 of the present article.] In flowing up a river the summit of the tide-wave reaches the different stations later as these are farther from the mouth; and in the Thames it advances from Margate to London, a distance of 70 miles, in three hours. It is observed also that the current of a river runs upward during some time after the summit has passed any station, and downwards for some time after the surface of the water is at the lowest; the intervals between the times of low and high water, moreover, gradually diminish as the stations are farther up, while the intervals between high and low water increase.

From the observations made by the committee of the British Association in 1836, on the tide-waves of the river Dee in Cheshire, it was found that the first wave of flood-tide advanced 5·275 miles in intervals of time varying from forty-five minutes to one hour, or, at an average, at the rate of 6·4 miles per hour; and that the wave of high-water advanced the same distance with a velocity, by an average of the observations, of 14·6 miles per hour. It is said however to have been impossible to determine whether the wave which carried the flood-tide to the lower station was the same as that which carried it to the higher. It is thought probable that the wave which passed the lower station was diffused in the spaces between certain projections from the bank on one side of the channel, and was overtaken by a subsequent wave from the sea. The wave of high-water, being above those obstructions, flowed up more regularly, and the observed height of the wave approached very nearly to that which is due to its observed velocity: it being understood that the velocity of a wave is that which would be produced by a body falling from rest through half the height of the wave.

In order that the phenomena of the tides at different places may be readily compared together, charts have been constructed, on which are drawn curve-lines joining the points at which high-water takes place at the same times. Now, since the heights of the wave and the times of its greatest elevation vary at every place from day to day, it is necessary to fix on the height attained at a particular time; and on this account, by general agreement, the time of high-water at every seaport on the days of full and change of the moon is chosen. This is called the "Establishment of the Port;" and an extensive table of "Establishments" for the ports of Great Britain and Ireland is given in the 'Nautical Almanac;'* the hours and minutes indicating the time from apparent noon on the days of new and full moon when high-water takes place. Since, on the first of these days, the moon passes the meridian with the sun, the time of high-water on any other day may be found from the table by merely adding the "Establishment" to the time at which the moon comes on the meridian on the given day. Finding upon the surface of the earth and sea any number of points at which the "Establishment," when reckoned according to Greenwich time, is the same, a line drawn through all the points will indicate the summit of a great tide-wave at that time: drawing a curve in like manner through all the points at which the "Establishment" in Greenwich time is an hour later, there is obtained a new position of the summit; and it must then be understood that the wave has travelled, in the sense above explained, from the first line to the next in one hour. These are called "Cotidal lines;" they were first indicated on a chart of the world by Mr. (now Sir John W.) Lubbock, in the 'Philosophical Transactions' for 1831, and an extensive series of such lines is traced on the chart which accompanies Dr. Whewell's 'Essay towards an approximation to a Map of Cotidal Lines,' in the 'Philosophical Transactions' for 1833.

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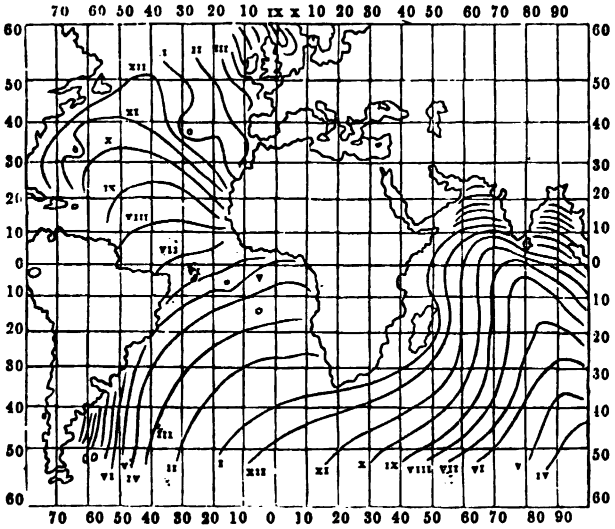
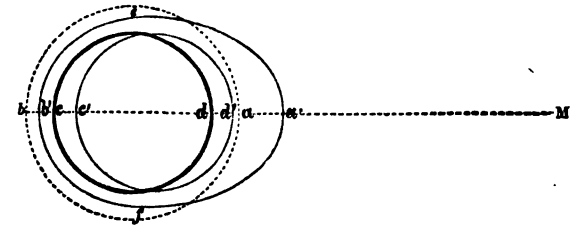
* In the 'Nautical Almanac' this information is now given in tables of the "Time of High Water on the Full and Change of the Moon," not only at ports and places in the British islands, but on the neighbouring shores of foreign countries.

The definition above given of the "Establishment" is only approximatively true: it is observed by Dr. Whewell, in the 'Essay,' that it would be correct if the high-tide always occurred when the moon's hour-circle makes equal angles with the meridian; but in fact the hour of tide on any day is reckoned from the time that the sun is on the meridian; and as the moon changes her right ascension every day by about forty-eight minutes (the observed hour of the tide being given on the day of new or full moon), the moon's hour angle may differ according to the time of the day when the conjunction or opposition takes place, compared with the time of day when the high tide is observed. Therefore an observation of the hour of the tide on the day of new or full moon may leave an uncertainty of about 1h. 8m. in the time of the "Establishment," unless account is taken whether the morning or afternoon tide was observed, and at what hour the syzygy took place.

The subjoined cut, which shows the principal cotidal lines in the Indian and Atlantic oceans, is from Dr. Whewell's chart above mentioned, and contains the modifications introduced in that which is given by Mr. Airy, in his Essay on 'Tides and Waves,' in the 'Encyclopædia Metropolitana.'



In investigations relating to the tides, it is required to determine the form assumed by the surface of the water when the particles are subject to the actions of disturbing forces; and for this purpose it is convenient to assume that if no such forces existed, the earth would consist of a solid spherical nucleus within a body of water whose exterior surface is that of a sphere concentric with the nucleus. Let the circle cd represent the nucleus, and the circumference ab the surface of the surrounding water in a plane passing through the centre of the earth, and the sun or moon at M: then, in the theory indicated by Newton, the attraction of the celestial body will draw the particles of water towards it so that the surface ab will assume the form $a'b'$; at the same time the attraction exercised on the solid part cd will cause the latter to take the position $c'd'$. Thus at the same instant the surface of the water at a' and b' is farther removed from the centre of the earth than it would be if there were no perturbation; while at e and f it is nearer the centre. If the celestial body were constantly in the plane of the equator, the summit of the elevated water would also be in that plane, and exactly or nearly under the body. A section of the spheroid of water passing through the poles of the equator and the summit just mentioned would be an ellipse, and its periphery would coincide with the direction of a terrestrial meridian. By the diurnal rotation this tide-wave, as it may be called, would appear to move about the earth from east to west at the rate of above 1000 miles per hour at the equator; and its positions at the end of every hour would constitute a series of cotidal lines. Hence, if a small island at the terrestrial equator were to project above the surface of the water, it would arrive successively at the points a', e, b', f, a', so that in the time of a rotation of the earth on its axis with respect to the celestial body, there would occur at the island two states of high-water and two of low-water. The arrival of the island at the summit a', which would, if M were the moon, take place at the end of every 24 h. 50 m. nearly, is called the diurnal tide; and that which takes place when the island arrives at the summit b', that is 12 h. 25 m. after the former, is called the semidiurnal tide. By this theory there ought to be scarcely any tides near the poles, the water being always drawn from them towards the tropical regions; and the attractions at a' under the celestial body being greater than the attractions at b', it should follow that the diurnal tide is greater than the semidiurnal tide, neither of which circumstances, however, is conformable to observation.



If an island having a great extent from the equator towards the north and south were to intercept the tide-wave, the elevated water, passing round the extremities of the island, would on its western side form two waves, which would advance towards, and meet one another at the equator, making, at different places on the coast, high-water successively later, in the directions of their motions. And it is easy to conceive that the tide-wave of a great ocean will send branches into any seas which it may approach in its movement about the earth: such are called derived tides.

The combined actions of the sun and moon, when those luminaries are in conjunction or opposition, that is, at new or full moon, may be readily conceived to produce what are called spring-tides; and the diminution of each other's attractions when in quadratures, to produce the neap-tides. It may further be understood that, as the distances of the sun and moon from the earth vary by the ellipticity of the orbits, at the times when either of the celestial bodies is in perigee, its attractive power being greater than at other times, the tide-wave raised by it will attain a greater elevation than usual: on the other hand, when in apogee, the high-water elevation must be the least.

The tides are greatly modified at any station or port by the position of the latter with respect to the equator, and by the declination of the sun and moon. The two summits of the great tide-wave are, at the same instant, diametrically opposite to one another; and if the latitude of the station were equal to the moon's declination on a given day, both moon and station being for example north of the equator, the summit of the wave would on that day be at the station when the moon is in or near the zenith; but about twelve hours afterwards, the station, having described half the circumference of a circle about the earth's axis by the diurnal rotation, will be on the opposite of the meridian; and the summit of the wave, being on the southern side of the equator, will be at a distance from the station equal to twice the moon's declination; consequently the height of this tide will be much less than that of the former tide. The contrary phenomenon occurs when the moon and the station are on opposite sides of the equator.

Among the tide-waves with which we are best acquainted are those of the Indian and Atlantic oceans; and from the known times of high-water at different places, it is ascertained that the summit of a wave advances from the seas to the south of Australia into the Bay of Bengal, and towards the Persian Gulf, causing the hour of high-water to be successively later at the ports from Ceylon northwards, on both sides of the western peninsula of India. The summit of a single wave seems to extend from the mouth of the Red Sea, along the eastern coast of Africa, to the Cape of Good Hope, where it joins the tide-waves of the Atlantic. These advancing northwards, cause the time of high-water to be successively later at the different ports on the western coast of Africa and Europe, and on the whole eastern coast of South and North America; so that the wave which at a certain instant is at the Cape, in 15 hours from that time is at the mouth of the English Channel and on the western coast of Ireland. This wave, being apparently checked in its progress by the British Isles, divides itself into two principal branches, of which one flows up the Channel, and passing through the Straits of Dover, is off the mouth of the Thames in 8 hours from the time that it was at Brest. A small branch advances up St. George's Channel; but the second principal branch of the wave flowing round the northern extremity of Scotland, proceeds slowly down the North Sea, and meets the first branch off the mouth of the Thames in 20 hours from the time that it was at the entrance of the Channel.

From Rio Janeiro to the Falkland Islands a wave summit seems to advance directly from east to west; and from the form of the continent of South America, the high tide occurs successively later in going southward from Cape Frio, as if the wave came from the north. The wave from the southern ocean sets northward, from Tierra del Fuego and the Falkland Islands to the coast of Patagonia, and at Port St. Elena on that coast it occurs 12 hours later than at those islands. On the western coast of America the tide travels from north to south, between Acapulco and the Straits of Magelhaens; while from the former place it travels northwards. In the Pacific Ocean the general direction of the tide-wave is from east to west; but the heights of the tides are small, not exceeding 2 feet at the islands of the South Sea. It is observed however by Dr. Whewell ('Phil. Trans.,' 1833), that this must not be understood to be the tide which would be raised if the whole earth were covered with water, on account of the modifications produced by the form of the continent of South America. The most eastern part of New South Wales, between 25° and 30° S. lat., has the high-tide earlier than points which are situated towards the north or south of that tract.

Peculiarities in tides, arising from the interference of tide-waves, occur in many different places. In the middle of the North Sea there is a considerable space within which the tide produced by the tide-waves coming from the north and south takes places at one time. And Dr. Whewell states, on the authority of the late Captain Hewett, that about the Ower Shoal there is no sensible rise of the tide till 3 hours after the time of low-water; but when the ebb stream has nearly ceased, there is a sudden rise of 5 or 6 feet; so that nearly the whole rise of the tide occurs in the last three hours.

In 1740 the Académie des Sciences offered a prize for the best memoir on the theory of tides: and the paper by Daniel Bernoulli on the flux and reflux of the sea shared it with those of Euler and Maclaurin. In that paper it is assumed that the water is kept in equilibrio between the attractions of its particles towards the earth's centre of gravity and the disturbing forces exercised by the sun and moon; and though the results of that theory are found to differ greatly from the observed phenomena, the theory itself is deserving of attention, since the analytical expressions which have been obtained by it first exhibited the several phenomena distinctly from one another: those expressions consequently became guides to the observer or experimenter in his efforts to ascertain the true values of the particular effects which they represented.

The attraction exercised by the solid nucleus of the earth on a particle of water at any distance from its centre, being considered the same as it would be if all the matter of the nucleus existed in that centre, is represented by $\frac{\text{E}}{r^2}$, E being the mass of the earth and r^2 the square of the distance of a particle from the centre. But if x, y, and z are rectangular co-ordinates of a particle, the centre of the earth being the origin, we have $r^2=x^2+y^2+z^2$; and the partial differentials of the expression $\frac{\text{E}}{x^2+y^2+z^2}$, relatively to x, y, and z, represent the effects of that attraction upon a particle in the directions of the three axes. If the attractions of the particles of water for each other are taken into consideration, there must be determined the attraction exercised upon a particle by all the water between the spherical nucleus and the exterior surface (supposed to be spheroidal) of the surrounding fluid, and the expression for this attraction must be added to that for the solid.

The disturbing force of the sun or moon upon a particle of water is represented by $\frac{\text{S}}{\text{R}^2}$, S being the mass of the celestial body and R the distance of the particle of water from it; and the partial differentials of that expression relatively to x, y, and z give the values of the attraction in the direction of the coordinate axes: but the disturbing force exercised by the sun or moon on a particle of water being equal to the difference between its attraction on the particle and its attraction on the centre of the earth—the latter, which is represented by $\frac{\text{S}}{\text{D}^2}$ (D being supposed to be the distance between the centres of the earth and celestial body), is subtracted from the attraction exercised on the particle in the direction of one of the coordinate axes, supposed to be parallel to the line joining those centres, in order to have that difference. The attracting forces of the earth in the directions of the three axes being subtracted from the disturbing forces of the sun or moon in the same directions, there remain three terms which are usually represented by X, Y, and Z. And since it has been demonstrated by mathematicians that when a body is in equilibrio under the action of attracting forces, the expression $\text{X}\,dx+\text{Y}\,dy+\text{Z}\,dz$ is an exact differential; the form of the surface of equilibrium is determined by making the integral of the expression constant.

The resulting equation being found to correspond with the general equation to a spheroid, a comparison of like terms in the two equations gives the values of the constants which enter into the former. If r represent the mean distance of the spheroidal surface of the water from the centre of the earth, and $\pm h$ represent the distance of any point on that surface above or below the mean level; then $x^2+y^2+z^2=(r\pm h)^2$ at the surface; and the determination of h for any place gives at that place the height of the water above, or its depression below the mean level.

Uniting the effects of the solar and lunar disturbances by simply adding them together, since the disturbing forces are very small compared with the force of gravity; and introducing, in place of the rectangular coordinates, angles which depend on the longitude and latitude of a station, with the right ascension and declination of the sun and moon, the value of the term $\pm h$ may be shown to consist of three parts: one of these depends on the variation of the declination of the sun and moon, and indicates a slow tide which goes through its changes in about fourteen days; the second depends on the hour angles both of the sun and moon, and indicates two tides which go through their changes in a solar and a lunar day respectively. These being combined, there is produced a diurnal tide, the highest state of which should precede, at a variable interval, the moon's culmination between the times of passing from syzygy to quadrature, and should follow it between the quadratures and syzygies. It has been found, however, that the observed accelerations and retardations, and also the absolute elevations of the water, in very few cases agree with the results of the theory. [ACCELERATION AND RETARDATION OF TIDES.]

The third part depends upon the doubles of the hour angles just mentioned, and consequently indicates two semi-diurnal tides, which being combined constitute one such tide, whose highest state is variable. The nature of the expression shows that the semi-diurnal tide should be the greatest at the equator, and should diminish till it vanishes at the poles: it denotes also that it is greatest at new or full moon, and least at the quadratures. The theory moreover indicates that the difference between two consecutive tides ought to be very considerable in Europe; whereas they are known to be nearly equal to one another. Both Newton and Bernoulli endeavoured to explain this circumstance by the hypothesis of a general oscillation of the sea, in consequence of which the highest tide gives to the lowest a quantity equal to the difference between them; but the researches of La Place have shown that, even with such oscillations, the two tides could not (according to the theory) be equal unless the sea were everywhere equally deep.

Euler, departing from the hypothesis that the sea is always in equilibrio under the action of the sun and moon, endeavoured to introduce the subject of fluid oscillations in his theory of the tides; but the laws of undulation were not then known, and Euler assumed that a molecule of the sea in motion endeavours to regain the position which, in a state of equilibrium, it would occupy in a vertical line with a force proportional to its vertical distance from that position.

The theory adopted by La Place, in which there are taken into consideration the laws of the motion of fluid molecules when acted on by attracting forces, was a great improvement on that of the mathematicians before mentioned; and it is found to produce a more near agreement with the observed phenomena. The elaborate investigations of La Place will be found in the 'Mémoires de l'Académie des Sciences' for the years 1775, 1776; and in the first and fourth books of the 'Mécanique Céleste.' They are also given, so far as contained in the first book, in the late Dr. Thomas Young's 'Elementary Illustrations of the Celestial Mechanics of Laplace;' Lond., 1821. As in the former theory, the solid nucleus of the earth is supposed to be entirely covered with water of uniform depth; and the investigations commence with the proof ('Méc. Cél.', liv. i., ch. 8) that any portion of the water, however its place may be changed, will always retain the same volume. The equation expressing this law is called the equation of continuity.

A very small parallelopiped of water within that which covers the solid nucleus of the earth is acted upon by accelerative forces arising from pressures estimated in the directions of three rectangular coordinate axes whose origin is at the centre of the earth: the first is supposed to be parallel to the axis of rotation, and the others in the plane of the equator: one being directed to the equinoctial point and the other at right angles to that direction. The pressures are supposed to arise from the attraction of the earth, from the angular velocity of its rotation, and from the disturbing forces, and to tend towards the origin of the coordinates.

These pressures, which are expressed by partial differential coefficients relatively to x, y, and z, in the coordinate axes, are subtracted from the accelerative forces arising from the attraction of the earth, and the perturbations exercised by the sun or moon, by which the molecule would be made to recede from that origin; and the differences in the directions of the axes are represented by $\frac{d^2x}{dt^2}$, $\frac{d^2y}{dt^2}$, and $\frac{d^2z}{dt^2}$.

In these equations of motion the partial differential coefficients representing the pressures are transformed into others depending on the distance of the molecule from the centre of the earth, and on its latitude and longitude; while the perturbations of the sun or moon in the directions of the coordinate axes are expressed in terms of the right ascension and declination of the disturbing body, and also of the distances of the latter from the particle disturbed and from the centre of the earth. The result is that the expression for the altitude of a molecule of water above the mean level, in consequence of the perturbation produced by the sun or moon, consists of three parts ('Méc. Cél.', lib. iv., c. 1); the first does not depend on the rotation of the earth, and indicates a tide which goes through its changes in a long period; it may consequently be disregarded. The second depends on that rotation and on the hour angle of the disturbing body: it indicates the diurnal tides, or those which take place when the celestial bodies are on or near the meridian, above the horizon; and which follow one another at intervals of twenty-four hours for the sun, and about 24h. 50m. for the moon. The third depends on an angle equal to the double of that on which the second depends; and consequently it represents the semi-diurnal tide.

But the subject of waves and tides has been treated in conformity to the theory of undulations by Mr. Airy, the astronomer royal, in a valuable essay originally published in the 'Encyclopædia Metropolitana:' the investigations, though admitting of general application, are particularly adapted to the phenomena of tides in rivers and arms of the sea; and they are conducted by an analysis within the reach of persons acquainted with the ordinary processes of the differential and integral calculus.

As in the theory of La Place, there is formed an "equation of continuity," which is founded on the equality of a rectangular parallelopiped of water at rest, to the oblique parallelopiped formed, when the water is in a state of disturbance, by the new positions of the eight particles constituting the angular points of the former parallelopiped. But, as the water is supposed to be in a rectangular canal, the extent of the parallelopiped in the direction of the breadth of the canal is supposed to be constant; and therefore it is sufficient to assume the equality of the parallelograms which form a side of each in the direction of the length of the canal.

The canal being of uniform depth, the "equation of continuity" is expressed by

$$Y = -\int \frac{dX}{dx} \text{ (between 0 and } y\text{)}$$

where x and y are respectively the horizontal and vertical coordinates of a particle of fluid, and where X and Y are respectively the horizontal and vertical displacements of the particle by the action of the disturbing forces: the equation expresses a relation between those coordinates and the disturbances or displacements.

An equation of the pressure experienced by any particle from the forces which act upon it is next found in the following manner:—Let p represent the pressure in every direction on the lower part of a disturbed molecule of water in consequence of the height or weight of the filament of particles above it: then, the vertical coordinate of the particle being y' or $y+Y$, suppose in the element dt of time the vertical coordinate to become $y'+\delta y'$ (the vertical height of the filament above the molecule in that position being increased by the general rising of the wave), the pressure on the upper part of the molecule will be greater than before, and may be represented by $p+\frac{dp}{dy'}\delta y'$; consequently the molecule may be supposed to be pressed downwards by a force represented by $\frac{dp}{dy'}\delta y'$. Now, in order to render the expression for the hydrostatical pressure homologous to that which is employed for the force of gravity, it must be considered as accelerative, or as a motive-power divided by the mass; and therefore the accelerative pressure downwards becomes $\frac{dp}{dy'}$, which being added to g, representing the force of gravity and supposed to be constant, there arises $\frac{dp}{dy'}+g$ for the whole acceleration of the molecule downwards: hence there is obtained the equation

$$-\frac{d^2y}{dt^2} = \frac{dp}{dy} + g.$$

This equation being integrated between the limits for the bottom of the molecule and the top of the wave, gives the hydrostatical force by which a vertical filament of water descends, or that by which it is carried forward horizontally.

Let the slender column of water above the molecule have a horizontal breadth equal to h in the direction of x; then the horizontal pressure in front, by which the column is forced backwards, will exceed the pressure by which it is carried forwards by a force represented by $\frac{dp}{dx}dh$, or by an acceleration represented by $\frac{dp}{dx}$; therefore the horizontal acceleration forwards is $-\frac{dp}{dx}$: if extraneous forces, as the attraction of the sun or moon on the molecule, and the effects of friction, be together represented by F, when estimated in the direction of x, there arises the expression $F-\frac{dp}{dx}$ for the whole acceleration forwards; then the "equation of motion" becomes

$$\frac{d^2X}{dt^2} = F - \frac{dp}{dx},$$

which gives relations between the terms X, Y, x, y, and t. This "equation of equal pressure" and the "equation of continuity" constitute the theory of the motion of fluids in canals of uniform breadth.

The general equation representing the disturbance or displacement of a particle of water is the same as that which expresses the disturbance of a particle of light in the undulatory theory; and, in order to indicate oscillatory motion, both the horizontal and vertical displacements are represented by terms containing the sines or cosines of angles depending on the time t.

If it be assumed that

$$X = R\cos(nt-mx) + S\sin(nt-mx),$$

R and S being functions of y, the above equations of continuity and of equal pressure give, on the supposition that gravity is constant, that no extraneous forces act, and retaining for the present only the first power of $\frac{dX}{dx}$, or of the horizontal displacement

$$\frac{d^2X}{dy^2} + \frac{d^2X}{dx^2} = 0.$$

From these two equations are obtained the values of X and Y in terms of $A\cos(nt-mx)$ and $B\sin(nt-mx)$.

These values will not be altered if mx is increased or diminished by one, two, three, &c. whole circumferences, that is, if x is increased or diminished by $\frac{2\pi}{m}$, $\frac{4\pi}{m}$, &c., while t remains the same; therefore $\frac{2\pi}{m}$ is the value of the increments of x which correspond to points when the particles of water are in the same condition with respect to disturbance, that is, $\frac{2\pi}{m}$ is the length of a wave. Again, the values will not be altered if nt is increased or diminished by whole circumferences, that is, if t is increased or diminished by $\frac{2\pi}{n}$, $\frac{4\pi}{n}$, &c., while x remains the same; therefore $\frac{2\pi}{n}$ is the increment of time which corresponds to the particles of water being successively in the like state of disturbance, that is, $\frac{2\pi}{n}$ is the period of a wave, or the time between two successive formations of a wave-summit at the same place. Therefore $\frac{n}{m}$ is the velocity of the wave; and, from the value found for it by the theory, it follows that the velocity depends on m and on the depth of the water: the latter being constant, the velocity depends on the length of the wave, or it depends on the time in which a particle of water makes a complete vibration. If the length of a wave or the time of its vibration is given, the velocity will vary with the depth of the water.

From a table of the computed velocities of waves of different lengths and with different depths of water, it is found that when the length of the wave is not greater than the depth of the water, the velocity of the wave is proportional to the square root of its length: also when the length is not less than one thousand times the depth of water, the velocity is proportional to the square root of the depth, and is the same as that which a body would acquire in falling from rest through a height equal to half that depth. The greatest horizontal and vertical displacement of a particle being computed for different values of the length of the wave and the depth of the water, it appears that when the latter is great, compared with the former, as in the open sea, the motion of the water far below the surface is very small compared with the motion at the surface, and at a depth equal to the length of wave it is only about $\frac{1}{535}$ of the motion at the surface. On the same supposition, the greatest horizontal motion is equal to the greatest vertical motion. When the length of the wave is great compared with the depth of the water, as in tide-waves, the horizontal motion of the particles is nearly the same from the surface to the bottom, and the vertical motion varies with the distance from the bottom. On the same supposition, the vertical motion of the superior particles is much less than their horizontal motion.

The movement of a particle of water near the surface may be determined from the values given by the theory to X and Y: if the waves are small, so that A may be considered as equal to B, we have $(X^2+Y^2)^{\frac{1}{2}} = C$, a constant; which, being the equation of a circle, it follows that the particles move in the circumference of a circle whose radius is A; but if the length of the wave is great compared with the depth of water, the equation is that of an ellipse. These last deductions from the theory are conformable to what has been observed in experimental waves, as above mentioned. It follows that, in a long tide-wave flowing up a channel, the horizontal velocity in the direction of the wave's motion is the greatest at the summit of the wave—that is, at high-water: at the place of greatest depression—that is, at low-water—the motion is most rapid downwards; and at the mean level the water is for a time stationary.

In investigating theoretically the phenomena of waves by whatever cause produced, if the lengths of the waves are very great compared with the depth of the canal in which they move, it becomes necessary to retain the second and even higher powers of $\frac{dX}{dx}$, or of the horizontal displacement, in the equations of continuity and of equal pressure; but the vertical oscillations being then small, the value of $\frac{d^2Y}{dt^2}$ may be neglected. Then, if the perturbating actions of the sun and moon are not considered, the integration of the differential equation of equal pressure gives a value of the vertical displacement at the surface, or the height of the wave above the mean elevation, in terms which contain $k\sin(nt-mx)$ and $kx\sin(2nt-2mx)$, k being the depth of water in the canal. Tracing an undulating line whose ordinates are the values of that vertical height, corresponding to different values of x, the horizontal distance from the mouth of the canal, which is supposed to open to the sea; it is found that, near the opening, the front and rear slopes of the waves are of equal lengths and of similar forms; but as the distance from the sea becomes greater, the front slope is shorter and steeper, and the rear slope longer and more gentle. At a great distance the latter becomes nearly horizontal in the middle, and at length it divides into two parts, so that the wave becomes double. Near the sea, also, the time occupied by the rise of the wave is equal to the time occupied by its descent: at a certain distance the rise takes place in less time than the descent; and at a still greater distance the descent, after having been rapid, is checked, or changed into a rise, to which another rapid descent succeeds; so that there seem to be two tides, or elevations of the water, in the upper part of the canal, corresponding to one elevation at the mouth.

The value of $\frac{dX}{dt}$, or the velocity of the particles of water, is found also to contain the sines and cosines of the angles above mentioned; and, substituting in these the greatest positive and the greatest negative values of the elevation, it is found that the velocity corresponding to the first of these values—that is, at the top of the wave—is less than the velocity corresponding to the other; but the motion, in the first case, is up the canal, and in the other down it, and these are nearly the same as the greatest velocities of the water: consequently, the velocity of the flow of the wave in the canal is less than that of the ebb. The preceding conclusions relate to the case in which the water was at rest in the canal previously to the formation of the wave: in the event of the water having a general movement towards the sea, the time in which the wave rises, or the time from low-water to high-water, is still less than the time of the descent; but the difference between the two times is greater than in the former case.

If a section of the bed of the canal, instead of being rectangular, has the form of an isosceles triangle, the investigations show that the velocity of the wave would be equal to that of a wave in a rectangular bed whose depth is equal to half the perpendicular of the triangle. If the section were a parabola, the velocity would be two-thirds of that which the waves would have in a rectangular bed of equal breadth and depth.

When the water, still supposed to be in a canal of uniform breadth and depth, is disturbed by extraneous forces, as the attraction of the sun or moon, the term F in the equation of equal pressure is conceived to consist of two, one represented by H sin. $(it-mx)$ for the horizontal intensity of such force in the direction of x, and the other by G cos. $(it-mx)$ for the vertical intensity; and the equation for $\frac{d^2x}{dt^2}$ being then satisfied by the equation $X=\phi''(y)\sin.(it-mx)$, in which $\phi''(y)$ represents the second differential coefficient of a function of y, there is obtained a value of X at the surface of the fluid in terms of sin. $(it-mx)$, and a value of the height above the level of still water in terms of cos. $(it-mx)$. The wave thus indicated depends upon the continuance of the actions of the extraneous disturbing forces, and is designated by Mr. Airy the *forced* tide-wave. This wave, he observes, would cease to exist if those forces were to cease; but other waves resulting from the previous action would still continue to exist, and these he distinguishes by the name of *free* tide-waves. If the canal be supposed to surround the earth at the equator, the length of the forced tide-wave is equal to half the circumference of that great circle; and from the expressions for X and Y, it appears that the effect of the vertical disturbing forces on the phenomena of the tides is insignificant, almost the whole sensible effect being due to the horizontal force.

Taking into account the effects of friction, which may be considered as a horizontal retarding force proportional to the velocity, and which may consequently be represented by $-f\frac{dX}{dt}$; the value of X contains terms involving the sines and cosines of angles represented by $it-mx$ and $it \pm qx$, and the expression for the vertical elevation contains the sine and cosine of $it-mx$. The analytical expression arising from the introduction of this additional perturbation indicates the fact that the highest tides take place later than the times at which the disturbing forces arising from the action of the sun or moon are the greatest; and this circumstance gives to the wave theory an important advantage over those of Newton and La Place; for in both these theories the greatest tides take place when the force is the greatest.

In the case of a canal bounded at both extremities, the expression for X, the horizontal disturbance of a particle, is found to consist of two parts, one of which is the horizontal movement due to the disturbing forces, and the other a combination of free tide-waves, probably caused by reflexions of the forced tide-waves from the opposite ends of the canal. When a canal so bounded is of small extent, the horizontal motion of the particles is found to be the greatest in the middle of its length, and to diminish gradually to the ends, where it vanishes. There is proved to be no variation of level in the middle of the length, and the variation in other parts is proportional to the distance from the middle, the elevation at one end taking place at the same time as the depression at the other. It results, also, that the greatest horizontal and vertical displacements of the particles take place at the same time; whereas in other circumstances, from the circular or elliptical motions of the particles, the greatest horizontal displacements take place when the vertical displacements are zero, and *vice versâ*.

In a deep gulf open to the sea at one end and closed at the other, and in which the waters have a tidal fluctuation, the termination of the flow upwards takes place at the mouth a considerable time after high-water; but near the bottom of the gulf the difference between the times is very small. When a tide-wave is propagated up a river, the analysis shows that the vertical elevations of the wave, and also the horizontal motion of the particles of water, diminish continually as the wave advances: also the direction of the tide-current changes sooner after the instant of high-water than it would if friction were not considered. When a river runs on a declivity towards the sea, the latter being affected by tides, it is shown that the low-water at certain points up the river may be higher than the level of high-water on the sea.

The theory, of which a brief outline has just been stated, applies to what are called negative waves by a mere change in the sign of the coefficients of the trigonometrical factors. These waves are depressions below the general surface of the water, and, like the others, they have a progressive motion. Such waves, for example, are those which are formed by the paddles of a steam-boat.

All the theories concur in showing that the difference between the diurnal and semidiurnal tides is great in middle latitudes, and small at the equator and poles; and in this respect they are at variance with the actual phenomena. From observations it is found that this difference is as great at certain places near the equator as near the latitude of either tropic: it has also been found to be great at Petropaulowski and in Norfolk Sound, while in Europe it is small. It has been attempted to account for the latter circumstance by assuming that each tide-wave in this part of the world is composed of two, which flow towards the same place in opposite directions at intervals of about twelve hours. It is supposed that the semidiurnal waves of these tides, being in the same state or phase, produce together a like effect, but that the diurnal waves are in opposite states; so that the superior high tide of one wave coinciding with the inferior high tide of the other, they together produce a mean height of water differing but little from that of the united semidiurnal tides.

We cannot here enter into the details of the investigations relating to the theories of the oscillations of water, or the discussion of the experiments which have been made on waves in artificial canals, the methods of making observations on tides, and accounts of the particular tides in rivers and seas; but the experimental researches of Mr. Scott Russell have made so important an accession to our knowledge of waves, in its relation to practical as well as theoretical science, that this article would be defective without a summary of their results. The details of his experiments will be found chiefly in the 'Transactions of the Royal Society of Edinburgh,' vol. xiv., and in the 'Report of the Seventh Meeting of the British Association for the Advancement of Science.'

At the time when Mr. Russell's hydrodynamical researches were commenced, the celestial mechanics of the tides, as we have seen in the preceding portion of this article, had been analysed and explained in a manner satisfactory both to astronomers and mathematical physicists, but a great variety of considerations relating to the propagation of the tides along the surface of the globe—constituting their terrestrial mechanism—remained without explanation. The solar and lunar attraction having generated the tides, exercise little or no influence over the subsequent propagation of them. It is not until 50 or 60 hours after their creation that the tides reach our shores, having moved in the interval in every possible direction, and with every velocity from 100 down to 10 miles an hour. "This moving elevation of fluid," in the words of the committee on waves, appointed by the British Association in 1836, "may be conveniently designated a *wave*, and its history will be the history of the *tidal wave;* but to confer upon it the name of wave does not imply that its laws are those which belong to any other similar elevation with which we are acquainted. It was necessary to investigate the nature of this tide-wave—to examine the hydrodynamical mechanism by which it is transferred from one place to another—to determine the laws which regulate its form and its velocity—to ascertain if any relations exist between the form and dimensions of its bed, and its own form and rate of transference. These and many similar points," including also the effect of the wind upon the tide-wave, "were still unknown." Laplace, Lubbock, and Whewell had severally pointed out how much was required to be known, and the last had shown that a great number of curious facts in fluid motion had been established by the tide researches, some of which had been discussed and others instituted and pursued by himself, of which he expressed a hope that the theory of hydrodynamics would one day be able to render a reason.

Such having been the condition of science on the subject when Mr. Russell began his inquiries, the following is a condensed statement, but nearly in the words of the Committee, of the "*General Results*" he obtained, and which have eventually been found to possess much more than the value which had been anticipated.

1. The existence of a great primary wave of fluid, differing in its origin, its phenomena, and its laws, from the undulatory and oscillatory waves which alone had been investigated previous to the researches of Mr. Russell, have been confirmed and established. This wave was first observed by him in 1834.

2. The velocity of this wave in channels of uniform depth is independent of the breadth of the fluid, and equal to the velocity acquired by a heavy body falling freely by gravity through a height equal to half the depth of the fluid, reckoned from the top of the wave to the bottom of the channel.

3. The velocity of this primary wave is not affected by the velocity of impulse with which the wave has been originally generated, neither does its form or velocity appear to be derived in any way from the form of the generating body.

4. This wave has been found to differ from every other species of wave in the motion which is given to the individual particles of the

fluid through which the wave is propagated. By the transit of the wave the particles of the fluid are raised from their places, transferred forward in the direction of the motion of the wave, and permanently deposited at rest in a new place at a considerable distance from their original position. There is no retrogradation, no oscillation; the motion is all in the same direction, and the extent of the transference is equal throughout the whole depth. Hence this wave may be descriptively designated the great primary wave of translation. The motion of translation commences when the anterior surface of the wave is vertically over a given series of particles; it increases in velocity until the crest of the wave has come to be vertically above them, and from this moment the motion of translation is retarded, and the particles are left in a condition of perfect rest at the instant when the posterior surface of the wave has terminated its transit through the vertical plane in which they lie. This phenomenon has been verified up to the depth of 5 feet.

5. The elementary form of the wave is cycloidal; when the height of the wave is small in proportion to its length the curve is the prolate cycloid, and as the height of the wave increases the form approaches that of the common cycloid, becoming more and more cusped until at last it becomes exactly that of the common cycloid, with a cusped summit; and if by any means the height be increased beyond this, the curve becomes the curtate cycloid, the summit assumes a form of unstable equilibrium, totters, and falling over on one side forms a crested wave or breaking surge.

6. A wave is possible in forms of channel where the depth is not uniform throughout the whole depth. It appears however that where the difference between the depth of the sides is considerable, one part of the wave will continue during the whole period of propagation in the act of breaking, so as to show that in these circumstances a continuous wave is impossible. In other cases the ridge of the wave rises so much higher on the shallower part of the fluid as to produce a given velocity without exceeding the limits of equilibrium, and in those cases the wave becomes possible, and the velocity appears to coincide closely with that which we obtain by supposing the wave resolved into vertical elements, each having the velocity due to the depth, and then integrating. It results that:—

In the rectangular channel the velocity is that of gravity due to half the depth.

In the sloping or triangular channel the velocity is that due to one-third of the greatest depth.

In a parabolic channel the velocity is that due to three-eighths or three-tenths of the greatest depth, according as the channel is convex or concave.

The velocity of the great primary wave of translation of a fluid is that due to gravity acting through a height equal to the depth of the centre of gravity of the transverse section of the channel below the surface of the fluid.

7. The height of a wave may be indefinitely increased by propagation into a channel which becomes narrower in the form of a wedge, the increased height being nearly in the inverse ratio of the square root of the breadth.

8. If waves be propagated in a channel whose depth diminishes uniformly, the waves will break when their height above the surface of the level fluid becomes equal to the depth at the bottom below the surface.

9. The great waves of translation are reflected from surfaces at right angles to the direction of their motion, without suffering any change but that of direction.

10. The great primary waves of translation cross each other without change of any kind, in the same manner as the small oscillations produced on the surface of a pool by a falling stone.

11. The waves of the sea are not of the first order; they belong to the second or oscillatory order of waves; they are partial displacements at the surface which do not extend to considerable depths, and are therefore totally different in character from the great waves of translation, in which the motion of displacement of the particles of the fluid in the waves of the sea is greatest at the surface and diminishes rapidly. There are generally on the surface of the sea several coexistent classes of oscillations of varying direction and magnitude, which by their union give the surface an appearance of irregularity which does not exist in nature.

12. When waves of the sea approach a shore or come into shallow water, they become waves of translation, and obeying the laws already mentioned, always break when the depth of the water is not greater than their height above the level.

13. Waves at the surface of the sea do not move with the velocity due to the whole depth of the fluid; may they not move with the velocity due to that part which they do agitate, or to some given part of it?

14. A circumstance frequently observed when the waves break on the shore, has been satisfactorily accounted for by the examination of the constitution of the waves of the sea. It has been frequently observed that a certain wave is the largest of a series, and that these large waves occur periodically at equal intervals, so that sometimes every third wave, every seventh, or every ninth wave, is the largest. Now as there are almost always several co-existent series of waves, and as one of these is a long, gentle "under swell," propagated to the shore from the deep sea in the distance, while the others are short and more superficial waves, generated by a temporary breeze of reflections from the neighbouring shore; so it will follow that when the smaller waves are ⅓rd, or ¼th, or ⅕th, or in any other given ratio to the length of the larger ones, those waves in which the ridges of the two series are coincident will be the periodical large waves; and if there be three systems of coexistent waves, or any greater number, their coincidences will form periodical large recurring waves, having maxima and minima of various orders.

15. The tide-wave appears to be the only wave of the ocean which belongs to the first order, and appears to be identical with the great primary wave of translation; its velocity diminishes and increases with the depth of the fluid, and appears to approximate closely to the velocity due to half the depth of the fluid in the rectangular channel, and to a certain mean depth which is that of the centre of gravity of the section of the channel. It is, however, difficult to determine the limits within which the tide-wave retains its unity; where portions of the same channel differ much in depth at points remote from each other, the tide-waves appear to separate.

16. The tide appears to be a compound wave, one elementary wave bringing the first part of flood tide, another the high water, and as these move with different velocities according to the depth. On approaching shallow shores the anterior tide-waves move more slowly in the shallow water, while the posterior waves moving more rapidly diminish the distance between successive waves. The tide-wave becomes thus dislocated, its anterior surface rising more rapidly and its posterior surface descending more slowly than in deep water.

17. A tidal bore [Bore] is formed when the water is so shallow at low water that the first waves of flood tide move with a velocity much less than that due to the succeeding part of the tidal wave, as to be overtaken by the subsequent waves; or wherever the tide rises rapidly, and the water on the shore or in the river is so shallow that the height of the first wave of the tide is greater than the depth of the fluid at that place. Hence in deep water vessels are safe from the waves of rivers which injure those on the shore.

18. The identity of the tide-wave and the great wave of translation, shows the nature of certain variations in the establishment of ports situated on tidal rivers. Any change in the depth of the river produces a corresponding change between the moon's transit and the high water immediately succeeding. It appears from the observations in this report, that the mean time of high water has been rendered [illegible] minutes earlier than formerly, by deepening a portion of about [illegible] miles in the channel of a tidal river, so that a tide-wave which formerly travelled at the rate of 10 miles an hour, now travels at the rate of nearly 15 miles an hour.

19. It also appears that a large wave, or a wave of high water of spring tides, travels faster than a wave of high water of neap tides, showing that there is a variation on the establishment, or on the interval between the moon's transit and the succeeding high water, due to the depth of the fluid at high water, and which should, of course, enter as an element into the calculation of tide tables for an inland port on the sea shore. The variation of the interval will vary with the square root of mean depth of the channel at high water.

"These results give us principles," the committee on waves conclude, "1, for the construction of canals; 2, for the navigation of canals; 3, for the improvement of tidal rivers; 4, for the navigation of tidal rivers; 5, for the improvement of tide tables." But an equally valuable application, not however foreseen when these results had been obtained and examined, unless by Mr. Russell himself, was to the improvement of naval architecture. Of this, a brief account has already been given in the article Ship-Building.

After the publication of the report by the committee on waves, which contained the experimental investigation of which we have now given the principal results, the phenomena of waves engaged the attention of eminent mathematicians, who endeavoured to deduce from first principles the curious facts which Mr. Scott Russell and his associates had observed, so as to reconcile theory with experiment. Among these were the Astronomer-Royal (a summary of whose conclusions has been given in this article), Mr. Green, and Professor Kelland, who also succeeded in obtaining from analysis many of the very singular experimental results. Their researches were published in the Transactions of the Cambridge Philosophical Society, and those of the Royal Society of Edinburgh; and Professor Kelland also gave a view of the actual state to which the theory of waves had been brought in the Report of the tenth meeting of the British Association.

The theory of waves, regarded as forming a part of abstract mechanics, as well as in certain applications, has been considered also in the articles Acoustics; Interference; Vibration; and Undulatory Theory of Light. An excellent familiar explanation of the subject, especially as regards the coincidence and interference of waves, will be found in Professor Tyndall's 'Glaciers of the Alps,' pp. 230–233.

WAX. There are several varieties of this substance, but the term used by itself means Bees' Wax, under which heading will be found an account of the manner in which it is secreted, its chemical constitution, and the means employed in preparing it for commercial purposes.

Wax is used to a considerable extent in the making of candles, cerates, ointments, and plasters. The so-called *sealing-wax* has no wax in its composition. [Sealing-Wax.] Spurious wax is sometimes made and sold for cheap purposes; consisting of yellow resin, mutton suet, and palm oil, or turmeric instead of palm oil. *Etching-wax* is made of bees'-wax and linseed oil; or white wax, gum benzoin, and linseed oil; or white wax, Burgundy pitch, and powdered asphaltum. *Modelling-wax* is described under Wax-Modelling.

Vegetable Wax. Various plants yield a substance like wax, which is obtained, like the vegetable butter, by bruising and boiling them in water, when the wax, melting, floats to the surface, and there concretes on cooling. Of these the most remarkable instance is the *Ceroxylon andicola*, the Wax Palm (*Palma de Cera* of the American Spaniards). *Myrica Gale*, Candleberry Myrtle, or Sweet Gale, a native of this country, yields a substance resembling bees'-wax when its catkins or cones are boiled in water. *Myrica cerifera*, a native of North America, yields a similar substance when its berries are thus boiled: candles are made of it also, whence the plant is commonly called Tallow-shrub or Candleberry-tree. *M. quercifolia*, a native of the Cape of Good Hope, is another species which yields a vegetable wax. It grows along the coast, on dry sandy plains exposed to the sea-air, where hardly any other plants will vegetate. The wax invests the berries in the form of a rough crust, which is separated by means of boiling water. It is of a greenish colour, but may be bleached. When made into candles it gives a very fine light. A vegetable wax is also obtained in China from *Ligustrum lucidum*, which is frequently mentioned as the wax-tree in Dr. Abel's and other travels.

Japan is now known to be the chief country whence vegetable wax is imported. Small parcels have been brought to market for many years past; the wax being at first in the form of small thin oval cakes stamped with Japanese characters. Afterwards it came over in cases containing 130 lbs. each. In 1859 a cargo arrived direct from Nagasaki, in Japan, of nearly 9000 cases. It commanded a ready sale at the price of the best Russian tallow at that time, (57*s.* per cwt.), but went off slowly at the required price of 70*s.*

Dr. M'Gowan, in a paper read before the Society of Arts in 1860, on the productive industry of Japan, said:—"One of the most remarkable products is the vegetable wax, several cargoes of which have already arrived in this country from Japan. It is said that the first adventurer in this article sold his cargo at 100 per cent. profit. The Japanese, having discovered this wax to be a valuable article of commerce, seemed, when I was in the country, to be making arrangements for cultivating more largely the trees producing the berries from which the wax is expressed; and, with improved machinery, this article could, no doubt, be produced more abundantly and more cheaply. The product requires protracted bleaching before it arrives at the white state in which it is sent to our markets."

Many other plants yield a substance similar to vegetable wax, some from the stem, but mostly from the berries. The *Rhus succedanea*, a plant of the same species as the *sumach*, might (it has been suggested) be profitably cultivated in Australia or at the Cape of Good Hope. It yields a wax residue, in quality between bees'-wax and vegetable tallow, softer and fatter than bees'-wax, and easily kneaded. It has already come into use in England in the candle manufacture. If combined with any cheap tallow or fat, it makes a mixture useful for many purposes.

WAX-MODELLING. Wax has been in all ages an important agent in the art of statuary; and in the formative art generally, whether as a fine art, or for the purposes of science. In statuary it is used in making the models for the metal cast, but more formerly than at present, for now clay is frequently substituted in its place: it is, however, still used by silversmiths in casting cups and other cylindrical or spherical objects, especially such as are required to be kept free from the markings of joints, to avoid injury to the design or embossed work. In fine art it is used in forming images, and iconic portraits, small busts, and bassi-rilievi; and it is also very usefully and largely applied in the preparation of anatomical models, especially in pathology, and in the preparation of fruit, flowers, and many objects of natural history. Wax-modelling, when applied as above described, as a fine art, is frequently termed the *Ceroplastic* art (κηροπλαστική; from κηρός, wax, and πλαστική, the art of fashioning into forms).

Wax was formerly indispensable in metal-casting, though when and how it was first used is wholly unknown. It may have been used for the models of solid casts even in the earliest periods, but was almost certainly used in hollow casting, which was a later invention, and which will presently be described; though of an art so entirely practical, no description can convey more than a general idea.

Different writers of different ages give various directions for the preparation of the wax to be used. Vasari, who doubtless mentions that used in his own time, recommends the admixture of a little tallow, turpentine, and pitch, with the common yellow wax, but he does not specify any particular quantities. The tallow renders it more soluble and fluid, the turpentine more adhesive, and the pitch colours it, and assists it in hardening after the operation is complete: it may also be coloured with a little red ochre in powder, which must be mixed with the wax in its liquid state. It may be made any other colour in the same way. A French mixture is—to one hundred pounds of yellow wax, ten pounds of turpentine, ten of pitch, and ten of hogs'-lard, which probably would be similar in its properties to the mixture described by Vasari. When the wax is melted, great care must be taken that it does not boil, or it cannot be repaired when cold. M. Fiquet, in his 'Art du Mouleur en Plâtre,' gives the following compound for founder's wax—to four of wax, mix one of tallow and two of Burgundy pitch (*poix de Bourgogne*), which when melted together are fluid and manageable. This was probably the composition used by J. B. Keller and Girardon in preparing the mould for Girardon's equestrian statue of Louis XIV., which was cast entire, or in *whole getto*. Several other mixtures were and are probably employed by different sculptors; the above, however, were those employed in France and Italy in the great ages of founding, when the wax method was generally in use. We may now proceed to describe the methods of its application.

Andrea Verrocchio, a celebrated sculptor of the 15th century, is said by Vasari to have been one of the first among the moderns to introduce casting from moulds taken from life, or, in Vasari's words, to bring the practice into general use—"che fu de' primi che cominciasse a metterlo in uso" (ed. 1568). These casts he made in wax and in plaster; and some writers have spoken of him as the inventor of moulding from the human figure, and others even as the inventor of casting in plaster; neither of which is said nor could have been intended to be conveyed by Vasari. Many arts have been known, and occasionally practised, before they have been applied to the ordinary uses to which they were well adapted. There is in Florence still preserved in the cathedral a cast thus formed from the head of Brunelleschi, which, as Bottari has remarked, must have been taken when Verrocchio was only fourteen years of age. And with regard to casting in plaster, if metal casts were made long before the time of Verrocchio, it is more than probable that plaster casts were also made. The first distinguished Italian founder of modern times was Andrea Pisano, who modelled the gates of the Baptistery of St. John at Florence, which were cast by some Venetian founders in 1330. The same sculptor had previously sent by Giotto a present of a bronze crucifix to Pope Clement V. (1305-1314) at Avignon, which must have been about 120 years before Verrochio was born. This crucifix is represented as having been of excellent workmanship; it must have been fashioned consequently by an artist or artists well acquainted both with mould-making and with casting, and the idea, therefore, that either art can have been ever first *practised* at so late a period as Verrocchio is quite untenable. The fact of bringing artists from Venice to cast the gates of the Baptistery of St. John does not so much show that Florence was without good metal-founders, as that Venice had obtained celebrity for its artists of this class. William Austen, a celebrated English founder, was anterior to Verrocchio. [Austen, William, in Biog. Div.] However, at whatever period and by whatever process the early Italians first prepared their moulds for metal-casting, they most probably in all works of consequence used wax in the preparation of the model for the casting. The ancient Greeks and Romans also most probably used wax for the same purposes. There are few ancient bronzes of a large size now extant; the principal of them is the equestrian statue of Marcus Aurelius before the Capitol at Rome. This monument is hollow, and was cast in two parts; and probably the ancient method was not very different from that described by Vasari; some ancient works were cast solid. The ancients were also in the habit of making plaster moulds of objects; in fact the Greeks and Romans were more or less familiar with almost every method and contrivance known to the modern statuary. (Müller, 'Handbuch der Archäologie der Kunst,' §§ 305, 6.)

It is generally allowed that the triumph of casting in modern times was Girardon's colossal statue of Louis XIV., cast by J. B. Keller; it stood on the Place Vendôme at Paris until 1792, when it was destroyed by the French populace. The weight of the monument is said to have been 60,000 lbs., and its height, including the bronze pedestal, 21 feet. This enormous mass of metal was cast at once, or in a single *getto*. The preparation of the model and mould was on the following plan:—When the model of the statue was finished, a safe mould of plaster and brickdust was made from it in many parts. [Modelling.] Each of these parts being marked and numbered, and removed from the model, was then oiled, and carefully filled on the inner side to a certain thickness, an inch or two, with the modelling-wax already described; the thickness depending upon the height or position of the part, the lowest parts being the thickest, for the metal is destined to fill exactly the space occupied by the wax. When all the parts of the mould were thus prepared, the whole was again put together in a pit, around a simple framework of iron bars, so as to support it firmly in each direction; the lowest parts of the mould being first placed, and the joints of the wax of the various contiguous parts being filled in, and the pieces carefully united together with melted wax with a brush, as the work proceeded. When the whole was put together, it was bound on the exterior with strong bars of iron attached to the extremities of the bars of the interior framework. The mould is now a hollow shell, with a thick coating of wax all over the interior, the whole being kept together by iron supports, inside and outside. The next step is to fill this hollow shell, through an aperture left at the top, with a composition of plaster and brickdust, which is fire-proof. This fire-proof body is termed in English a *core*, by the French *noyau*, by the Germans *kern*, and by Vasari the *anima*. Air-vents must be made in the shell before the casting of the core.

When the core is fixed, the original mould or shell is taken off, and a wax model of the statue appears to the eye. The sculptor now examines his wax model, and improves it where there is occasion and repairs or makes good all imperfections. When it is perfectly finished, the preparation for the founding commences. Over this wax statue a new fire-proof mould is made of plaster, brickdust or sand, cow-hair, and horse-dung, and sometimes very fine ashes. This composition, used at first as a fine liquid plaster, is put on in many coats with a brush, and care must be taken that every particle of wax is covered with the finer plaster: each coat is allowed to dry before the successive coat is put on, and the composition may be gradually made of a coarser mixture. When this new shell or mould is of a sufficient thickness and is properly strengthened by iron bars, a coal fire must be kindled round it and be allowed to burn until the whole of the wax is burnt out, proper vents being made for its escape. This burning out of the wax is a most tedious and difficult process, lasting sometimes as much as four or even six weeks. (Söltl, 'Bildende Kunst in München,' Stiglmayer, p. 484.) The great difficulty and long process of melting out the wax was the cause of what is called the wax method going comparatively out of use, but it is only recently that the clay and sand modelling as its substitute has been generally established. Until 1824 Stiglmayer, one of the most successful of recent founders, used the wax method; from that time the clay method. The largest single cast by Stiglmayer did not amount to one-half of the given weight of this enormous cast by Keller: it is, however, now no longer considered desirable to cast a monument in a single *getto*. [BRONZE; SCULPTURE.]

When the wax is at length melted out, the mould must be strengthened by brickwork, and the whole pit must be closely filled with sand. A channel is now made from the furnace, and is divided in its course into three smaller channels or ducts which lead to three openings in the now hollow mould, which is buried in the earth a little below the furnace. The vacuum in the mould caused by melting out the wax is to be filled with metal; the original iron framework, which was constructed before the casting of the core, keeps both the core and the mould in their proper places; and air-vents in various parts of the mould preclude any great probability of accident. When all is ready, the furnace is opened at a given signal, the liquid fire runs in the channels simultaneously into the mould, and that part of the work which was previously soft wax becomes perennial bronze. The cast is accomplished when the metal pours out from the vents. When cool, the mould is broken away piecemeal, and the metal is exposed. The core is then removed from the inside through an aperture made on purpose; the whole is then repaired and finished by the bronze-workers. [BRONZE.] Johann Balthasar Keller, who cast in this method the statue of Louis XIV., was a Swiss, and originally a goldsmith. He was born at Zürich, in 1638, and died at Paris, superintendent of the royal foundry, in 1720. There is a print of the statue by C. Simoneau: it was cast in 1699.

Vasari (*Introduzione*, l. c.) describes a very simple method for casting small figures in bronze. When the mould (*cappa*) is made, it must be reversed in water; melted wax is then poured into it, that coming in contact with the cold wet surface of the mould cools immediately, while the interior portion remains liquid; the mould must be again turned over, when the still liquid wax in the centre will immediately run out, leaving in the mould a hollow wax shell. The shell must now be filled with the proper plaster, and this constitutes the core of the object. The wax is then burnt out, and the cast is made as usual.

It remains to treat of that department of wax-modelling termed *Ceroplastic*. Under this term is comprehended modelling and casting in wax, though not in the manner already described. The art of casting in wax from nature was, according to Pliny ('Hist. Nat.' xxxv. 44), invented by Lysistratus, of Sicyon, the brother of Lysippus, about 300 B.C., who, he says, first of all men took plaster moulds from the face and made wax casts from them. These wax portraits became eventually very common, and especially among the Romans. It is however very unlikely that the many treasured wax portraits we read of in ancient writers were made from moulds taken from the face itself. Such would be the mere resemblance of death, for they would be without eyes and otherwise void of expression. They were probably cast from moulds taken from models, though such masks may have been used in the formation of the models.

From Pliny (xxxv. 2), we learn that the Romans were in the habit of having wax images of themselves made, to be handed down to their posterity. Many writers notice and praise the custom. Valerius Maximus (v. 8. 3), alludes to the advantages of the practice by virtue of example. It was indeed a privilege to which only some were entitled. None could make them but those who had themselves, or whose ancestors had, borne some curule magistracy. Cicero speaks of the right of handing down your image to posterity. The number of ancestral images therefore became an object of pride and an evidence of ancient nobility, and the antiquity of a family was sometimes expressed by applying the epithet smoky to its images, "fumosæ imagines." (Cicero in 'Verr' vi. 14.; in 'Pisonem,' 1.; and 'De Leg. Agrar.' ii. 1.)

The most striking passage concerning these images is in Polybius (vi. 52), who as a Greek and a stranger would be more impressed by so peculiar a custom as he describes. He says, "Upon solemn festivals, these images are uncovered, and adorned with the greatest care. And when any other person of the same family dies, they are carried also in the funeral procession, with a body added to the bust, that the representation may be just, even with regard to size. They are dressed likewise in the habits that belong to the ranks which they severally filled when they were alive. If they were consuls or prætors, in a gown bordered with purple; if censors, in a purple robe; and if they triumphed or obtained any similar honour, in a vest embroidered with gold. Thus apparelled they are drawn along in chariots preceded by the rods and axes, and other ensigns of their former dignity. And when they arrive at the forum, they are all seated upon chairs of ivory; and then exhibit the noblest object that can be offered to a youthful mind warmed with the love of virtue and of glory."

This wax-modelling has continued apparently from the time of the Romans until the present day. In the middle ages it was used for the images of saints and votive images. The first modeller however of this class noticed in the history of art is Orsino, the contemporary of Andrea del Verrocchio, in the middle of the 15th century. Vasari represents Orsino as a wax-modeller (ceraiuolo) of good repute in Florence, and that he attained, through the advice of Verrocchio, the highest excellence in his art. Verrocchio and Orsino made some interesting figures together, of which three of Lorenzo de' Medici are worthy of especial notice: they are described by Vasari as something remarkable. The conspiracy of the Pazzi in 1478 was the cause of the production of these figures: they were voted by his friends in commemoration of his escape. Orsino made, under the direction of Verrocchio, three wax images of Lorenzo of the size of life. The framework or skeletons of these figures were made of wood and cane, and the heads, hands, and feet were cast in wax, of considerable thickness, but hollow; they were then furnished with hair and glass eyes, and painted in oil-colours to the exact imitation of life; and were draped in clothes which had been worn by Lorenzo; to give the draperies a fixed character they were waxed. These figures were altogether so successful, says Vasari, that they appeared to be living. One of them was placed in the church of the Monache di Chiarito, in the Via di San Gallo; another in the Servitant church of the Annunciation; and the third in the church of Santa Maria degli Angeli at Assisi. In this Servitant church were many other wax figures by Orsino, all of which were marked with an O, in which was an R, and above it a cross; but they have all long since perished. Vasari adds that few works of later wax-modellers were to be compared with those of Orsino, and complains that the art had declined. A few years however after the death of Vasari, Jacopo Vivio distinguished himself by a model on slate, in coloured wax, of Michel Angelo's Last Judgment in the Sistine Chapel. It was engraved by Ambrosio Brambilla, and a particular description of it was published in Rome in 1590—'Discorso sopra la mirabil opera di Basso-Rilievo di cera stuccata con colori, scolpita in pietra nera, da Jacopo Vivio."

Two centuries after Verrocchio, and one after Vasari, this art was very usefully and with the utmost skill applied by Gaetano Giulio Zummo, born at Syracuse in 1656, to the preparation of anatomical models and pathological examples. Zummo obtained a European celebrity for his two groups of figures representing the various stages of corruption of the human body and the effects of the plague. He modelled also an anatomical head at Paris, which is described in the Mémoires of the French Academy of Sciences, of 1701, the year of his death.

The first collection of anatomical preparations which was made for the purposes of science is that of the Institute of Bologna, established by Benedict XIV. It was commenced under the direction of Ercole Lelli, but the greater part of the preparations were made by Giovanni Manzolini of Bologna and his wife Anna Morandi Manzolini. Manzolini died at Bologna in 1755, aged 55. There are some of his models in London and in many other cities of Europe. Anna Manzolini obtained still greater celebrity than her husband: she executed all or the greater part of the obstetric models in the Stanza Ostetricia of the Institute which were prepared under the direction of Dr. Antonio Galli. She also gave public lectures on anatomy in Bologna, illustrating her discourse by appropriate models. She died in 1774, aged 57. (Crespi, "Felsina Pittrice," where there are portraits of both the Manzolini.)

There is a still more extensive and remarkable collection of wax anatomical models in the Museum of Natural History at Florence: it was established by the Grand-Duke Leopoldo, and occupies fifteen chambers. It contains the works of various artists, but the principal contributors to its treasures were, Felice Fontana and Clemente Susini. The works of the earlier modellers in wax are set apart in a chamber by themselves: here are some of the models of Zummo, among which is one showing the whole anatomy of the human head, similar probably to the one made at Paris.

The Musée Dupuytren at Paris is celebrated for its morbid specimens; it is perhaps the richest pathological collection in the world. It was purchased by the University of Paris, of the heirs of M. Dupuytren, the celebrated anatomist. Most of the principal cities of Europe have now their collections, and some of them very fine ones, and good wax-modellers are numerous.

In this department of modelling none but the purest wax is used, which is the case also in all works where the wax is the final substance of the work. Different modellers use different compositions; and some allowance must be made for hot and cold weather, as what would be well adapted for summer weather might be too brittle for winter use. Some modellers use simply wax and a small proportion of Venetian turpentine; others wax, resin, common turpentine, and a little olive-oil; the wax being at least two-thirds of the whole composition. It is seldom if ever used pure, as in all objects to be modelled white or some colour must predominate: for instance in modelling the brain, white in powder must be mixed in the composition, and the same respect must be had with regard to the predominant colour of every object to be modelled.

No strict rules can be given for the process of modelling, as each modeller will soon acquire methods of his own, and generally speaking artists of this class object to disclose their peculiar processes, imagining it to be detrimental to their interests. However, we may speak of general principles. Nearly all wax models are cast from moulds, and the casts only in some cases require the assistance of modelling: these moulds are generally taken from the objects themselves, either in plaster of Paris or in a composition of bees'-wax, Burgundy pitch, and Venice turpentine, with a very small quantity of olive-oil. The advantage of this latter composition is, that even when cold, if properly mixed, the mould is elastic or flexible; and if made thin, when cut on the edges can be peeled off the cast in pieces without any danger to the cast: in taking moulds in plaster of Paris, the object moulded must sometimes be destroyed to render the mould available. Gelatine is now sometimes employed for making elastic moulds. Round objects must be moulded in two or more parts. Sometimes when the object is cast in the mould, the mould must be destroyed before the cast can be removed, and in destroying the mould there is danger of destroying the cast also; the *elastic* mould therefore has great advantages in such cases over the plaster mould. When only one view of an object is presented, and it is only slightly convex, the plaster mould is quite sufficient, except the object itself, as the brain, presents a very uneven and delicate surface. When the cast is to be taken from the plaster mould, the mould must be moist with water, but not absolutely wet, or the water would injure the very delicate surface, which occurs in some pathological cases: the mould may be moistened by allowing it to stand with the interior or face uppermost in a dish of water, when it will soon absorb sufficient moisture for the purpose. The mould must not be oiled when any delicate work is to be done, as the oil will dissolve the surface of the wax, and thus perhaps counteract the principal aim of the cast. The wax composition mould must be slightly touched with a soft hair-tool with oil, to enable it to peel away afterwards without the slightest danger to the cast: being of a perfectly smooth surface, the small quantity of oil it retains is immaterial.

When the cast is made, and what they call *backed up* (that is, strengthened with a coarser composition within), the process of painting commences; but all effects cannot be given by mere colour, some morbid deposits and effects require to be expressed by adding wax of the proper colour with a hair-pencil or other tool. The colouring is done from the natural object represented, with fine hair-pencils and powder colours moistened with turpentine and tempered with a little wax; simple water is also sometimes used as the colouring vehicle. When the colouring is finished, the whole is covered with mastic varnish. In cases where the morbid effects or evidences of disease are of a distinct substance from the healthy texture, different coloured wax should be used in casting the healthy and diseased portions, and the parts may be corrected by modelling. The same process must be employed in modelling fruit and other objects of natural history, as in preparing anatomical models: but fruit, which is generally in full or high relief, will require piece-moulds, that is, to be moulded in several pieces, which is done half or part at a time. Flowers are not all cast; they are prepared from leaves of coloured wax made expressly for the purpose. These leaves are cut the required shape; they then, with the necessary colour and a hair-pencil, receive their local tints; and are finally joined and fashioned into the required flower. Insects are modelled by combining the two processes. In moulding objects with hair or delicate raised parts, a little oil must be carefully put over the parts, unless they are wet. Dry firm objects may be moulded without oil; the plaster must be removed as soon as it is set.

It remains yet to speak of the mode of making images. These likewise are made in various ways; but the essential process is casting. A head may be simply cast, and, when the hair and eyes have been added to it, the local tints be given with turpentine and colour. This method however uses a considerable quantity of wax, and various devices have been had recourse to to save wax. One mode is to cast the pure wax thin, and to back up or fill in to a considerable thickness with a coarse composition of bees'-wax, resin, and cow-hair or tow; in casting images the mould may be oiled. Ordinary heads however may be made in this manner:—Let a thin block head be fashioned in a mould or otherwise, of coarse paper pulp and size; when dry it must be coloured all over with flesh-tint, the local colours being put on, a higher degree than is natural, as also the colours of the cheeks, lips, and eyebrows; the whole may then be covered with wax, which must be poured over it two or three times, until the surface is well covered; its regularity may be secured by retarding the cooling of the wax and assisting it to run, by means of a hot iron or burner (called *cauterium* by the ancients), which must be held near it until the whole has a uniform surface. The colour originally painted on the paper block will show through the wax, and the head will require but the hair, the eyes, and a few local touches to finish it. Masks may be also dipped in wax, or the wax may be put on with a hair-tool, if the mask be kept warm; or a wax cast may be backed up or strengthened with strong paper pulp. There are however other methods of modelling wax figures, but no method can be properly explained by a verbal description; such mechanical processes must be witnessed to be understood: for this reason this article has been limited to mere general principles, which is as much as the general reader can require or understand.

Sculptors are in the habit of making wax models of small objects in the round, or for bassi-rilievi to be cast in metal, in the same manner and with the same tools that common clay models are made of: the same wax is used as is required for casts. [Modelling.] Medals and small bronzes are generally modelled in wax. Impressions from seals, engraved gems, and cameos are taken with wax. The wax, which is prepared with a little powdered sugar-candy, turpentine, and lamp-black, after being melted, is preserved in small cakes. These cakes when wanted are softened by repeated pressure of the fingers, and are then compressed into or upon the seals or cameos, previously wetted, from which the impressions may be required.

WAX, SEALING. [Sealing-Wax.]

WAY, *Chîmin* (from the French *Chemin*), is a term used to denote either a right, in one person or more, of passing over the land of another, or the space over which such right is exercisable. In the former sense a way is an incorporeal right of the class called Easements.

There are five kinds of way:—1. A foot-way, for persons passing on foot only; 2. A horse-way, for persons passing on horseback, but including a foot-way; 3. A drift-way, for driving cattle; 4. A carriage-way, for leading or driving carts and other carriages, always including a foot- and horse-way, and usually, but not necessarily, including a drift-way; 5. A water-way for ships and boats. [River.]

All these may be either private or public ways. Private ways are enjoyed by particular persons or classes; public ways are open to all persons; hence such a way is said to be *communis strata*, or *alta via regia*—in the language of pleading, a common and public queen's high-way.

I. The proper origin of a private right of way is, a grant from the owner of the soil.

Such a grant may be made to a party, or to him and his heirs *in gross*; that is, without respect to any land or house of which he may be the owner or occupier: or to the grantee, his heirs, and assigns, *being* owners of such a house or close; in which case the right granted will be *appurtenant* to the house or close to which the grant is annexed, and the right will pass with the house or close.

The grant of a way may be either express or implied; and in the case of an express grant, the grantor may impose such restrictions upon his grant as he thinks proper. If a man at the time when he conveys part of his land to another, has no access to the land conveyed, except over the land which he reserves, the grant of a right of way over the land reserved is implied. If a man conveys part of his land, and has no access to the part reserved, except over the land conveyed, a right of way over the land conveyed is impliedly reserved. The way so impliedly granted or reserved is called a "way of necessity."

Where no deed can be produced whereby a way is expressly or impliedly created, the party who claims the way may, in the case of a long-continued user of the right without evidence of commencement or interruption within the period of legal memory, plead that it has been immemorially enjoyed by him and his ancestors in the case of a way in gross, or by him and all those whose estate he has, in the house or close to which the way is annexed, in the case of a way appendant (that is, immemorially appurtenant).

Until lately also, a lost grant would be presumed in ordinary cases, after an uninterrupted and unexplained user of twenty years. The rule of law as to prescription for ways is settled by 2 & 3 Will. IV. c. 71, s. 2. [Prescription.]

A grant of a right of way made by a person who has only a limited estate in the land over which the way passes, is effectual only during the continuance of the estate of the grantor. If a claim to a right of way is set up in respect of the twenty years' or the forty years' enjoyment mentioned in the statute, if it appear that the land over which the right is claimed has, during the whole or part of the twenty or forty years, been in the occupation of a party who had a limited estate in such land, not only is no right of way acquired against the reversioner, but no right whatever is gained by the user.

The party to whom a private road is allotted under the general enclosure act, has a *statutory* right of way.

If the party entitled to a way becomes the owner of the land over which it passes, the right of way is extinguished if the party has the same extent of interest in the land and in the way. But if the one be held for an estate different in extent of duration from the other, the right is only *suspended* during the union of the two interests. Even where a right of way is extinguished by unity of possession, it will, in some cases, revive upon a severance of that unity, as by partition among parceners, &c. A private right of way may also be extinguished by a deed of release executed by the party who is entitled to such way; and such a release may be presumed from a non-user for twenty years or from a declaration made by the party that he has no such right.

A way of necessity is limited by the necessity out of which it has arisen. If the party to whom such a way is impliedly granted, or by whom it is impliedly reserved, becomes entitled to some other access to his land, equally direct, the way of necessity is gone.

The particular rights of the grantee of a private way continue to exist notwithstanding the owner of the land may have dedicated it to the public as a high-way. The grantee cannot throw the burden of repairing the way upon the grantor, unless by the terms of the grant, evidenced by the deed or by user, the grantor has engaged to enable the grantee to use the way.

If the occupier of the land over which a private way passes, or any other person, obstruct the way, the party entitled to the way may remove the obstruction, and he may also bring an action on the case, or, in some cases, an action of covenant against the obstructor. On the other hand, if the occupier of the land resisting the claim of a right of way, bring an action of trespass against the person exercising the alleged right, the defendant may plead in justification a title founded upon prescription, grant, reservation, or statute.

II. Between private ways and public ways stand what may be called *quasi public* ways, which partake of the qualities of both, but differ in some respects from each. By some writers these are classed among private, by others, among public ways; they seem more properly to constitute a distinct intermediate class. Such are ways which the inhabitants of a town, &c., have immemorially used from their town, &c., to a church or market. A right of this description cannot, in modern times, be created. It cannot be the subject of a grant, inasmuch as inhabitants, as such, are not at this day capable of taking any interest by grant; nor can it, like a public way, be created by dedication. as a dedication of a way can only be to the public at large. Such a right therefore can exist only as the consequence of an ancient custom.

III. A highway is created where the owner of the soil has, by express words or by some act done or forborne, declared his intention that the public shall have the use of a way over such soil. The dedication of a way to the public may be by writing or by words; so that it may be inferred from the acts of the party, as the throwing down of fences, or from mere tacit acquiescence where the acquiescing party is in possession of the land, and therefore has the means, if disposed so to do, of preventing the use of the way. In all cases, however, it is necessary that the party dedicating should have a sufficient interest in the land to warrant such dedication. If he has a less estate than a fee-simple, his dedication will not bind the reversioner. But it would also appear that the owner of such a limited estate could not even dedicate a highway to the public for the limited period of his interest in the soil, and that his attempted dedication, however distinctly and formally made, would amount to nothing more than a licence revocable at pleasure.

When there is no express dedication, the presumption of an intention to dedicate, arising out of the conduct of the party, may be rebutted; as by showing that when the public were first admitted a bar or a chain was occasionally placed across the road, whereby passengers might, at times, be excluded; although it should also appear that the bar, &c., had long been omitted to be used, or that it had been suffered to fall into decay, or had been actually broken down, and that no attempt had afterwards been made to restore it.

A highway is frequently created by statute, principally under inclosure acts.

Whatever may have been the origin of a highway, it cannot, at common law, be destroyed or altered, except after an inquisition taken upon a writ of *ad quod damnum*.

By the common law the burden of maintaining highways is thrown upon the occupiers of lands and tenements within the parish, or rather within the township in which the way is situated. But particular persons may be bound to repair a highway. This special liability may exist by reason of enclosure (*ratione coarctationis*), against parties who have enclosed the sides, or one side of the road, and have thereby lessened the facilities for breaking out into the adjoining lands where necessary; or by reason of the possession of lands (*ratione tenuræ terræ suæ*), which have by some means become chargeable with the burden. In the case of a corporation aggregate, a liability to repair may also be established by prescription only, or ancient usage, without enclosure or tenure.

Any obstruction or other nuisance in a highway may be abated or removed by any person who chooses to undertake the task. The wrong-doer may also be proceeded against by indictment as for a misdemeanor; but he is not liable to an action, as he is in the case of nuisance to a private or to a quasi-public way, except in respect of special damage.

The regulation of highways has frequently been made the subject of legislative interference. The general statute now in force is the 5th and 6th Will. IV. c. 50.

In the case of a way over water, either private, quasi-public, or public, if the course of the water alter by sudden or gradual change, the way is continued over the new course. Every navigable river, arm of the sea, or creek, is a highway for ships and boats. [RIVER.]

WAY, MILKY. [MILKY WAY.]

WAYS, ROMAN. Our old chroniclers and writers give this na to four principal ancient highways which they suppose to have be either originally formed by the Romans in Britain during their occu- pation of the country, or at least to have been completed and perfecte by that people upon lines of road for the greater part already trac and used by the former inhabitants. The names however by whic the four highways are distinguished appear to be Saxon in for although they may be Roman or British in etymology: Watling-stre Ikenield-street, Ermine-street, and the Fosse-way. The Saxons n doubt adopted the Roman highways, but probably gave them new, o altered their existing names. Watling-street is held to have extende from Dover to Chester; or, according to another hypothesis, to Chester-le-street, in Durham, passing through Canterbury, London, and Verulam, from which last-mentioned town it had also the name of Werlam-street. Its remains, or supposed remains, are still known in various places by the names of High Dyke, High Ridge, Ridge Way, and Forty-Foot Way. There has indeed been much controversy as to whether Watling-street did actually pass through London; but the received opinion is, that it passed along the line of what is still called Watling-street in the City, meeting the other three great roads a branches from them at the central milliarium in Cannon-street, pointed out by the site of London Stone, and crossing the river at *Dowgate* to what is still called Stoney-street on the Surrey side. The northward course of Watling-street, after leaving London or its neighbourhood is supposed to have been over Hampstead Heath, to Edgeware, an hence, through Verulam (or St. Alban's), and Dunstable in Bedfordshire, to Stoney Stratford in Buckinghamshire, whence it skirted Leicestershire on the west to Bosworth, and thence proceeded in a north-western direction to Chester. Ikenield or *Ichenild*-street is sa to have been so called from its commencing on the eastern side of the island in the country of the Iceni, mentioned by Tacitus, and supposed to be the same with the Simeni of Ptolemæus, who appear to have occupied Norfolk, Suffolk, and Cambridge. On the supposition however of London Stone having been the central milliarium where all the great roads of the country met, a branch of the *Ikenield* must have extended to this point; it is supposed to have passed through Aldgate, and to have been otherwise known by the name of the *Vicinal Wa* The course of the Ikenield to the westward is *extremely* obscure: it appears to have crossed Watling-street at Dunstable, and thence extended first south-by-west to Dorchester, and thence westward through Devonshire and Cornwall. Ermine or Hermin-street, again, is conjectured by some to have extended from St. David's, at the south-western extremity of Wales, to Southampton; by others, *to have* stretched more directly across the country to London, which it may have entered by what is now called Holborn. From London it proceeded northward by Godmanchester to Lincoln, and thence *to* Winterton on the Humber, where was a ferry: beyond the Humber, roads proceeded northwards to Whitby, and north-by-west to York; and thence to the border, and later into Scotland. Finally, the *Fosse* is supposed to have taken its course from south-west to north-east, beginning near Totnes in Devonshire, and passing through Bath, Cirencester, Chipping Norton, Coventry, Leicester, and Newark, to Lincoln, where it united with Ermine-street. The courses of these and the other leading Roman roads through the several counties will generally be found described more particularly under the several counties in the GEOG. DIV. The whole subject of these supposed Roman highways is however obscure and undetermined. Yet it is certain that the entire face of the country was, during the Roman occupation, covered with a network of roads, and these four would seem to have been the main lines, while others branched from them at various points, so as to connect every important military station with London and other principal towns, and with each other. Generally the main or military roads were marked by directness of course; in many cases they are almost coincident with or parallel to the present roads. The branch or cross roads (*viæ vicinales*), the private roads (*viæ privatæ*), and the bye-roads (*deviæ*), were of course less elaborate in construction and less direct in course. Itineraries of the chief Roman roads in Britain have come down to us; that called of Antoninus is probably of the 4th century, that of Richard of Cirencester of the 14th century (of which however there are doubts as to the genuineness), and a less complete one compiled in Ravenna in the 7th century: each is believed to have been compiled from more ancient materials. The four great roads, with one or two more, such as Akeman-street, extending westward from London to Bath, may have been, as commonly supposed, the old British highways; but there can be little doubt that they were re-formed and reconstructed by the Romans. Vitruvius has left a full account of the Roman system of making paved ways [ROADS], and these English roads, though less elaborate in construction than those diverging from Rome itself, seem, from the appearance presented by their foundations wherever they have been dug up, to have been formed on the same substantial principle. Where they remain, they are still often in good order, although they were doubtless adopted by the Saxons, and continued to be used for a long period subsequently.

WAYWODE, or WOYEVODA, is a Slavonian appellation, derived from *voyna*, "war," and *rodit*, "to lead;" and consequently it has the same etymology as the Latin *Dux*, the Saxon *Heretog*, and the modern German *Herzog*.

This name was originally given to military commanders in different

Slavonian countries. In Poland each palatinate or province had its woyevoda, whose duty was to command in time of war the pospolite, or arrière ban of his province. The woyevodes had in time of peace a certain administrative authority, and composed the first class of the senators. By a rather improper comparison with the Comites Palatii of the empire, they were translated in Latin by "palatine."

In the earliest times of Russian history the appellation of woyevoda is given to high military officers. In Muscovy there were military and civil woyevodes: the first were simply generals, and Peter the Great abolished this ancient Slavonian appellation and introduced that of general. The civil woyevodes were divided into provincial and town woyevodes, and they were governors of provinces and towns: and this appellation was changed only under the reign of Catherine II. into that of governors, commanders, &c.

The appellation of waywode was assumed for some time by the rulers of Moldavia and Wallachia, who substituted for it afterwards the Greek title of *despota,* and finally its Slavonian translation, hospodar. The princes of Transylvania had likewise sometimes the title of waiwode, which was also given to some minor Turkish officers.

W is here pronounced as the English V.

WEALTH is the means of obtaining the products of labour. An individual is rich or poor according to the quantity of the necessaries and luxuries of life which he can purchase; and a nation is rich or poor, in the aggregate, according to its means of enjoying such advantages. Labour is the source of wealth, and every addition to its productiveness tends to increase wealth, by lowering the cost of commodities, and rendering them more easy to be obtained. Political economy treats mainly of the means of promoting the increase of national wealth, and of removing obstructions to its development; and it is the purpose of this article very briefly to enumerate and explain some of the chief principles of that science which bear directly upon the production of wealth. The first object is to encourage industry. This is best done by leaving it free to obtain an adequate reward, by protecting all persons in the enjoyment of such reward, and in reducing the amount or value of it as little as possible. These encouragements can only be effectually given in a free state, and under a civilised government, where property is secure, and labour free from restraint. Insecurity of person or property, arbitrary and oppressive taxes, monopolies, restrictions upon the free exercise of skill and enterprise, are all impediments to the increase of wealth: they discourage industry by diminishing the inducement to exert it, and they restrain its productive powers when exerted by thwarting the natural intelligence and activity of man in the pursuit of his own interests.

Whatever gives the best direction to industry, and facilitates its operations, is favourable to the increase of wealth. Thus the separation of men into different employments is highly useful, as it perfects their skill and ingenuity in their respective arts, and causes a general economy of time. Still more useful is capital, without which division of labour cannot be extensively practised. It puts labour in motion; combines the work of many hands; gives means and power to invention; creates mechanical aids to human labour, and finally distributes by degrees what it has assisted in producing. It is capital that incites and utilises improvements in machinery. Without capital, the inventor could not afford to give his time nor produce the improvement he had made. These improvements always occasion the employment of a more skilled, and, therefore, a better paid labour. And if they materially reduce the cost of the article produced, and it is one in large demand, they necessarily tend to the increase of the number of labourers, however much their first introduction may threaten the contrary. Facilities to the ready and effective application of capital obviously add to its utility; as credit, for example, which lends to one man the capital of another when he can employ it more profitably and the various descriptions of money (the representatives of capital) which facilitate and cheapen the exchange of labour and its products between man and man. The higher the *general* rate of profits in a country may be, the more rapidly is capital likely to be accumulated; because the majority of men are usually desirous of accumulating, and the means of doing so are evidently increased by high profits. If a profit of five per cent. upon a man's capital engaged in business enabled him to live in comfort, and to continue his business without any diminution of his capital; a profit of ten per cent. would enable him, at the same time, to add to it five per cent. annually, to be employed in further production and accumulation. It is clear that there can be no increase of capital in any country in which the rate of profits does not leave a surplus beyond the necessary expenses of living. In such a case capital would be stationary, while the population to be supported by it would be on the increase.

The advantages of division of labour have been already noticed. The enriching properties of commerce are of a similar character. By distinct employments labour is made more productive; by commerce, the natural products and the peculiar arts of different countries are exchanged with mutual benefit and economy of labour to all. In France and Spain the grape, grown in the open air, provides delicious wine: in England, to make such wine (if it could be made at all), the grape must be grown in hothouses. In England cotton goods can be manufactured more cheaply than in any country in the world. If France and Spain would buy them, they would save annually whatever excess of price they pay for similar goods made by themselves; while the capital and labour now applied to such manufactures could be added to their means of production. To understand the effects of free commercial intercourse, it is only necessary to keep in view its analogy to the common dealings of life. No man thinks of making anything himself if he can buy it for less than it would cost him to make it. He continues working at his own employment, and buys the article he wants. If he did otherwise, he would lose his own profitable time and labour, and the article made by himself would take still more out of his pocket than if he had bought it; while its quality would most probably be inferior, by reason of his own want of skill and practice in that particular work. The same principle applies to nations. Commerce extends to all countries the happy results of division of labour, instead of confining them to particular communities.

The last circumstance directly favourable to the increase of wealth, which need be noticed, is a cheap and expeditious communication, both in the interior of a country and with all parts of the world, for the transit of merchandise and for the carriage of passengers. Every deduction from the cost of an article is an addition to the national wealth, and the expense of transit forms no inconsiderable part of the ultimate charge upon the consumer. A saving of time also is an addition to the labour and productive energies of a country. The extraordinary resources added to labour by facilities of travelling by the railways in Great Britain is felt by every one. The importance of cheap and rapid modes of commercial intercourse, in other points of view, need not be pointed out.

In conclusion, the advancement of general knowledge and intelligence must be noticed as an agent in the production of wealth. It is the mind and the disciplined will of man which render all the circumstances of the world available for his benefit; and in viewing education chiefly as a social blessing, we should never forget to urge its merits as a producer of wealth, upon those who would regard its other recommendations with less favour.

WEANING, the act of separating a child from the partaking of its mother's milk as food. A few hours after the birth of a child, the breast of the mother secretes milk for its nourishment. The milk that is secreted at first differs in some of its properties from the milk subsequently secreted, and has been called *colostrum.* Healthy milk under the microscope is found to contain globules of various sizes, which are perfectly spherical in form, swimming in a fluid in which are suspended no other particles; whilst the globules of colostrum are irregular and disproportioned, some of them being very large and others very small. There are also in colostrum particles of a yellowish colour, which are very minute, and which consist of fatty matter and a peculiar mucus. The milk retains these characters for several days, and it has been supposed at this period to possess a purgative property, which excites the intestines of the young infant to throw off the accumulated meconium. When the mother is healthy, the secretion of milk goes on abundantly till the ninth or tenth month, at which time the infant is generally able to take some other kind of food, and the process of weaning may commence at this period. It however often happens, from ill health or other causes, that the mother is not able from the first to suckle her child. In this case the child must be either transferred to another nurse or fed artificially. The former, where possible, should always be preferred. In the choice of a nurse care should be taken that the infant is transferred to one whose age, size, and temperament resemble its own mother. There should also be an absence of actual disease or a tendency to hereditary disease, and of all habits likely to interfere with a due secretion of healthy milk. Where children are artificially fed or reared from birth by the hand, the greatest care and attention are required. The first requisite is that the child should have a food as nearly resembling its natural food as possible. For this purpose the milk of various animals has been employed. That of the cow, as being most easily obtained, is most frequently used; but it would appear that the milk of the ass most nearly resembles human milk, and on that account, where it can be obtained, is to be preferred. The following is the latest analysis by Dr. Playfair, of the milk of woman, the cow, and the ass, and may serve as a guide in the preparation of the food of children:—

	Woman.	Cow.	Ass.
Casein	1·5	4·0	1·9
Butter	4·4	4·6	1·3
Sugar	5·7	3·8	6·3
Ashes	0·5	0·6	..
Water	88·0	89·0	90·5

The milk of the cow contains a much larger quantity of the casein, or nitrogenised principle, than that of woman or the ass, and requires dilution previous to its being administered to new-born children. At first two-thirds pure fresh water and one of cows' milk, with a small quantity of sugar, may be employed. As the child grows older, the quantity of water should be gradually decreased till it takes milk alone. This food should be administered to the child at a temperature of about 98°, the heat at which the milk is supplied from the mother. When children are thus fed, a spoon should not be used, but some means should be had recourse to for administering the milk slowly, as the sucking-bottle, artificial nipple, &c. In feeding a child artificially, as in suckling, the first sign of indifference may be regarded as a sign that the child has had enough. On no account should children be fed again immediately after vomiting, a practice that is often extremely injurious.

As a child increases in size and strength, it requires other food in addition to milk, and at last ceases to require supplies from its mother. Although this is a perfectly natural process, it is often, from want of skill, or rather want of knowledge of natural laws, a source of painful disease to the mother, and sometimes even loss of life to the child. As a general rule, it may be stated that a child should never be suddenly weaned, and that the more gradual the separation between mother and child the better will it be for both. The time for weaning must depend in some measure both on the development and health of the child and the state and health of the mother. With regard to the child, one of the first indications that weaning may be commenced is the appearance of teeth. This is indicative of preparation for other kind of food, and generally occurs in healthy children about the sixth or seventh month; and it is at this period that a gradual abstraction of the breast may commence. If this be done, it is seldom that a child will require suckling beyond the first year; although, where no ill consequences result to the mother, there is no objection to the child continuing at the breast till it is eighteen months or two years old. Where children are backward in the development of their teeth, and present other signs of want of strength and delicacy of constitution, it is frequently advisable that they should remain a lengthened period at the breast. It is always necessary to take into consideration the health of the mother during suckling, as children may suffer much more severely from an imperfectly secreted or diseased state of the milk than they would from immediate weaning, and under these circumstances of course the least evil is to be preferred.

In order that the weaning should be gradual, the child should be induced at the fifth or sixth month to take some light food once or twice a day, and its supply from the breast should be proportionately diminished. If such a plan is pursued, the quantity of food administered by hand being increased whilst the supply from the nurse is decreased, it will be generally found that little difficulty will be experienced in entirely weaning the child at ten or twelve months old. After a child has been weaned its food ought principally to consist of liquid or semifluid substances. Asses' and cows' milk alone, or boiled with bread, thickened with barley or baked flour, may be given for the first few months. To these may be added, for the sake of variety, rice, tapioca, sago, and arrow-root, which may be made up with milk or water, or both; and when water alone is used, sugar should be added. Where children cannot take milk, light broths should be administered. As solid food for the first year after weaning, there is nothing better than bread and butter: but in all cases in the diet of children a due regard should be had to the relation between azotised and non-azotised aliments. If the former are given in too great quantity, congestion and inflammation are frequently the result; whilst if the latter prevail in the diet, the child gets fat and loses strength, and becomes subject to diseases of debility. Neither the one kind nor the other should be withheld, and it is only by their judicious combination that the fatal effects of improper diet can be avoided.

(Gardien, *Dictionnaire des Sciences Médicales*; Combe, *On the Management of Infancy*; Maunsell and Evanson, *On the Diseases of Children*.)

WEAR. [WEIR.]

WEARING. [VEERING.]

WEATHER is a term used to denote the state of the earth and of the atmosphere with respect to heat or coldness, dryness or humidity, wind, rain, &c.

In some countries the variations of the atmospherical phenomena occur in an order which is nearly constant; and in those regions, predictions concerning the weather for several days, and even for months to come, may be made with almost a certainty that they will be verified by the event. On the opposite sides of the chain of the Ghauts, which extends along the western peninsula of India nearly from north to south, the phenomena during each half of the year are constantly and exactly reversed: thus, along the Malabar coast there is a clear sky from September to the following April, and on the coast of Coromandel the fair season continues from April to September; while during each following six months, in the two regions, it rains almost incessantly. Alternations of fair weather and rain also take place regularly in the interior of Africa; and, according to Humboldt, it rains constantly during five or six months in every year from the coast of Guiana to the Andes. But in insular situations generally, and in Europe and North America particularly, the winds, varying in direction and intensity according to no constant known law applicable to the purpose, mingle together at intervals of time apparently irregular, the masses of air which abound with vapour raised from the ocean, and thus cause clouds to cover the horizon, and showers of rain, hail, or snow to descend. The wind which is most prevalent at any one place, generally when it begins to blow affords an indication of the kind of weather which may be expected; but, frequently, no circumstance occurs by which a change from a clear to a cloudy sky, or the contrary, can be predicted even a few hours before its occurrence.

The periodical changes of the moon's phases often coinciding with changes in the phenomena of the atmosphere, it was very natural that the latter should, by many persons, be thought to have some dependence on the former [RAIN, col. 929]; an opinion apparently strengthened the known fact that the tides of the ocean and atmosphere are produced by the attractions which the moon and sun exercise on the particles water and air. It is certain, however, that the influences of the moon in changing the state of the atmosphere are of short duration, and take place gradually according to constant laws: they are consequently quite incompetent to the production of those sudden and irregular changes to which the atmosphere is subject. There are not, however, wanting men who have formed tables in which the probable state the weather is stated in connection with the hour of the day or night at which the new and full moons take place; and that which seems to possess most the confidence of persons to whom an anticipation of rain or fair weather is of importance, is one which Dr. Samuel Clarke professed to have formed from a long series of observations. It is sufficient here to mention that in this table rain is predicted when the new or full moon takes place between noon and 2 P.M., or between 4 and 6 A.M. and fair weather is announced when either takes place between 4 and 6 P.M., or between 10 P.M. and 2 A.M. An opinion has prevailed that seasons of a like character return in like order after each revolution the moon's nodes; that is, at the end of every 18 or 19 years, at which times the earth and moon are nearly in like situations with respect the nodes; but though seasons distinguished by more or less than the usual quantities of rain have been observed to return at certain intervals, there appears to be no ground for connecting them with the astronomical period. The existence of a "Cycle of Eighteen Years in the Seasons of Britain," has been maintained by Mr. Luke Howard, in his work having that title; but the validity of the evidence adduced has been subsequently denied by the Rev. L. Jenyns, in a volume on Meteorology.

The only indications of rain or fair weather upon which any reliance may be placed are those which have been noticed by the late Sir Humphrey Davy, in his 'Salmonia;' and as his explanations are founded on physical conditions, a brief statement of them may with propriety be introduced in this place.

One of the speakers in the Dialogue inquiring why the clouds in the west being red, with a tinge of purple, should portend fair weather, is answered that the air, when dry, refracts more of the red and heat-making rays than when moist; and as dry air is not perfectly transparent, those rays are reflected in the horizon. It is added that a coppery or yellow sunset foretells rain; but that, as an indication of approaching wet weather, nothing is more certain than a halo round the moon, since it is produced by precipitated water: the larger the circle is, the nearer are the clouds; consequently the more ready to descend in rain.

In explaining why a rainbow in the morning betokens rain, and one in the evening fair weather, it is stated that the bow can only be seen when the clouds depositing the rain are opposite to the sun; thus in the morning the bow is in the west, and in the evening in the east: and as the rains in this country are usually brought by westerly winds, a bow in the west indicates that the rain is coming towards the spectator; whereas a bow in the east indicates that the rain is passing away from him.

The indications of fine weather from swallows flying high is explained by stating that the insects on which these birds feed delight to fly in a warm stratum of air; but warm air, being lighter than that which is moist, occupies a higher part of the atmosphere, and, therefore the birds then find their prey in the upper regions. On the contrary, when the warm air is near the surface of the earth, the insects and birds are there also; and then, as the cold air from above descends into it, a deposition of water takes place. The opinion that sea-birds come to land in order to avoid an approaching storm is stated to be erroneous; and the cause assigned is that, as the fish upon which the birds prey go deep into the water during storms, the birds come to land merely on account of the greater certainty of finding food there than out at sea.

It may be observed here, that the kind of cloud which is designated cirrostratus [CLOUDS], in which, when the particles of water composing it are in a state of approximate coalescence into drops, the halo is formed, is almost always followed by a depression of temperature in the atmosphere, and by wind or rain. For indications of the weather, which are afforded by the oscillations of a mercurial column, see BAROMETER; and for those which precede cyclones, or revolving storms, see that subject in the article WIND.

The observations of Principal Forbes (stated in the article VAPOUR, OPALESCENT) have shown that the red colour of the clouds is referrible to a different cause from that to which it is ascribed by Davy, in the citations above. But the red evening and gray morning have been regarded as the surest and most consistent signs of fine weather. They would naturally be observed from the earliest periods, and accordingly they appear to be the most ancient of prognostics, having been recorded in the verses of the Greek poet Aratus, who was contemporary with Euclid; in the New Testament (Matt. xvi. 2, 3); and in one of our most familiar proverbs. The purple tinge alluded to, according to Principal Forbes, probably arises from a mixture of the reflected blue of the pure sky, which is always present when purple is seen, with the yellow-orange of the opalescent vapour.

"The modified hues of the sky, and of the sun and moon near the horizon, have, for so many ages and in so many countries, been regarded as the surest indications of atmospheric changes, that we cannot doubt that it is to the variety of conditions in which vapour exists in the air, more or less nearly condensed, that these phenomena are due. Humboldt describes the colour and form of the sun's disc at setting in tropical regions, as the most infallible prognostic, and elsewhere ascribes these variations 'to a particular state of the vesicular vapour.' Since the red steam [opalescent vapour] occurs only during the critical stage of its partial condensation (and perhaps conversely during evaporation), it is evident that it must correspond to a critical state of diffused vapour in the atmosphere. . . . . Every accurate observer of nature in alpine countries will confirm me in stating that fine weather is almost invariably accompanied by the formation of dew on exposed surfaces, and by the progressive depression of the moister strata, until at length visible fogs are formed in the bottom of the valleys, and especially over water. (For the reason why over water, see Davy [MIST]). This is the surest sign of a following fine day in mountainous regions. . . . . The inflamed appearance of the morning sky, considered indicative of foul weather, is, I have no doubt, owing to such an excess of humidity being present that clouds are actually being formed by condensation in the upper regions, contrary to the direct tendency of the rising sun to dissipate them, which must therefore be considered as indicating a speedy precipitation of rain." ('Phil. Mag.,' series 2, vol. xv., pp. 34-37.)

Principal Forbes expresses a strong doubt as to the formation of any "vesicular" vapour in the process of the condensation of atmospheric vapour; on which it may be remarked that the existence of such vapour (that is, in fact, of vesicles of water produced by the condensation of vapour) under any circumstances is altogether hypothetical, as noticed in considering the nature of the spray of WATERFALLS. According to observation, when vapours become liquids, minute globules geometrically solid are formed: the globules of dew are such.

Principal Forbes, also, as we have seen, is of opinion that the opalescent vapour occurs "perhaps conversely during evaporation," as well as condensation. This we are able to confirm from our own observations, made long before he had enabled us to understand them. It may be proved by a ready experiment. If a plate or a saucer be plunged into nearly boiling water and withdrawn, it will be covered with a film of water, which the heat acquired by the porcelain will immediately convert into vapour, rendering the plate dry. If, on withdrawing it from the water, it be immediately held up to the light, a pink blush, as it were, will be seen, momentarily, before the steam-cloud resulting from entire condensation. During evaporation in nature the same phenomenon must of course take place: it may readily be observed on Derwentwater, looking northward, on a summer morning, when Skiddaw and the adjacent mountains may be seen through a transparent mist, having a pale pink or rose-coloured hue; the evaporating water below constantly supplying opalescent vapour, the appearance is persistent so long as the sun is acting and the atmospheric circumstances are unaltered, notwithstanding the perpetual resolution of the opalescent into invisible vapour above. This connects the subject with the colours of the sky and the prognostics of the weather derivable from them. A part of this subject, also, is considered in the article just referred to. In the article on OPALESCENT VAPOUR itself we have expressed our dissent from Principal Forbes as to the process by which the colours of the morning sky are produced, deeming it to be merely the reverse of that occurring in the evening. We think it might be shown "that the slowly progressive transition of vast masses of air through the temperature of the dew-point" must occur at sunrise as well as at sunset; of this, the "beautiful rosy tint, shooting far up into the heavens," described as preceding the dawn, when observed from Mont Blanc, is one of many examples that might be mentioned in evidence, according entirely with the facts already noticed, which the distinguished physicist whose views we have been considering first recognised in their due importance. [CLIMATE; METEOROLOGY.]

WEAVING. If we take the term *weaving* in its broadest sense, as applied to the process of combining longitudinal threads into a superficial fabric, it will have relation to the whole series of textile manufactures; not only those which are prepared in the loom, but likewise net-work, lace-work, and hosiery. We shall endeavour therefore in the present article to complete the details of manufacturing many textile fabrics which have been partially described in former articles.

History of Weaving.—From many passages in the Bible, and from the general character of dress, it is apparent that woven fabrics were known in very early times. In all probability weaving was practised before spinning; that is, the combination of reeds, strips of leather, or rude fibres into a material for dress, by a process analogous to that of weaving, preceded the practice of spinning yarn from a congeries of elementary fibres. Sir J. G. Wilkinson ('Manners and Customs of the Ancient Egyptians') observes,—"The Egyptians, from a most remote era, were celebrated for their manufacture of linen and other cloths; and the produce of their looms was exported to, and eagerly purchased by, foreign nations. The fine linen and embroidered work, the yarn and woollen stuffs, of the upper and lower country, are frequently mentioned, and were highly esteemed." The same authority states that the looms, found depicted on the tombs at Thebes, are of an exceedingly rude construction; but he does not think that this circumstance militates against the production of fine fabrics, since it is known at the present day that the Hindu produces exquisite muslins on his rude loom. In a specimen of mummy-cloth, examined by Mr. Thompson of Clitheroe, the texture was close and firm, yet elastic; the yarn of both warp and weft was remarkably even and well spun; the weft was single, while the warp-yarn consisted of two fine threads doubled; and it was observable, in that as well as in other specimens, that the number of threads to an inch in the warp uniformly exceeded that in the weft, a difference not commonly observable in European fabrics. Mr. Thompson examined ancient Egyptian cloths brought to England by Salt and Belzoni, and found that the selvages were well made, that striped goods similar to modern ginghams were often made by the Egyptians, and that indigo was used as one of the dyes. Wilkinson gives copies from some of the pictures at Thebes, Beni Hassan, and Eileithyas, representing weavers at their looms; in one instance the loom appears to be horizontal, while in another it is vertical, with the weft driven upwards; and from representations of five different sorts of shuttles, it would appear that they were generally about half a yard in length.

Weaving appears to have been carried on as a distinct trade in the larger towns of Greece; but every considerable private establishment had also a loom at which the females of the family were employed; the weaving being carried on chiefly by female slaves, while the superintendence rested with the mistress and her daughters. In large houses a particular room was set apart for this occupation.

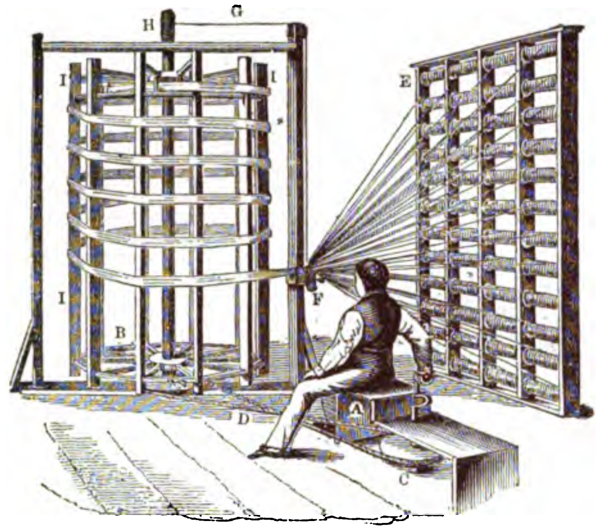
Plato mentions one of the most important differences between the warp and the weft, namely, that the threads of the former are strong and firm in consequence of being more twisted in spinning; whilst those of the latter are comparatively soft and yielding; a comparison which is strictly applicable at the present day. The Greeks evidently understood much of what is now termed "mounting a loom," that is, arranging strings in such a manner as to separate the warp-thread into two or more groups, between which the weft may be introduced: the leash (*μίτος*) being one such string, and a woven pattern being termed *δίμιτος* (from which the word *dimity* appears to be derived), *τρίμιτος*, or *πολύμιτος*, according as it contained two, three, or more groups of strings, or, as we should now say, leaves of heddles. After the weft was thrown, it was driven up close, either by a kind of bat, called a spatha, or by a kind of comb; both of which appear to be combined in the batten, or lay, of the modern loom. The checks produced by having different coloured warp threads, and stripes, formed of multi-coloured wefts, were known to the Greeks and Romans; as were likewise numerous kinds of fancy weaving derived from these two combined. Among the Romans, as among the Greeks, weaving was a female employment, and, as with them, it was carried on in most towns and in many large private establishments. Weaving, as practised among the ancients, may be illustrated by the proceedings of the weavers among existent imperfectly civilised nations. The Hindu weaver takes his station under the trees, where he stretches his warp-thread between two bamboo rollers, which are fastened to the turf by wooden pins. He digs a hole in the earth large enough to contain his legs when in a sitting posture; and then, suspending to a branch of a tree the cords which are intended to cause the raising and depressing of the warp-threads, he fixes underneath two loops for his toes, by which he produces a substitute for treadles. His shuttle acts also as a batten, or lay, and completes his simple arrangements.

We shall now proceed to describe the weaving processes, classifying them under the names of *Plain-weaving, Pattern-weaving, Double-weaving, Cross-weaving, Chain-weaving, Pile-weaving,* and *Power-weaving,* —giving cross references to former articles, in which some of these subjects have been treated.

Plain-weaving.—By this term we mean the weaving of all varieties of textile manufacture, in which the weft-threads interlace uniformly among the warp-threads without producing twills, checks, stripes, sprigs, or any variety of figures. Calico, Irish linen, and plain silk are good representatives of this kind of weaving. If we examine any of these, we shall find that the cross threads pass alternately over and under the long threads, no one thread passing over or under two other threads at once. In the language of weavers, the long threads are called *warp, twist, caine,* or *organzine;* while the cross threads are called *weft, woof, shoot,* or *tram.* Twist is the general term applied to the kind of yarn used for cotton warp: organzine to that for silk warp; and some of the other terms have in like manner only partial application: if therefore we speak simply of *warp* and *weft,* we shall avoid ambiguity, and be sufficiently correct for the object in view. The warp is always affixed to the loom or weaving-machine; while the weft is contained in the shuttle, a small boat-like instrument.

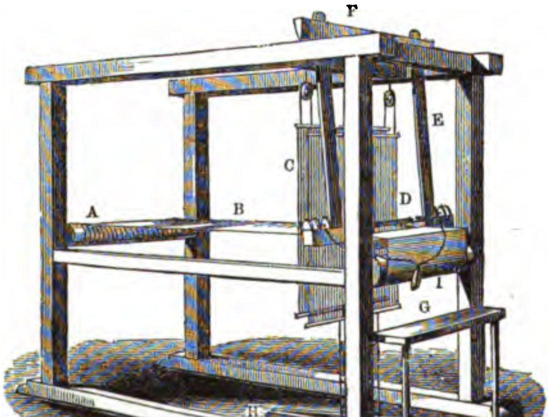
The first operation consists in laying the requisite number of threads together to form the width of the cloth: this is called *warping.* Supposing there to be 1000 threads in the width of a piece of cloth; then the yarn, wound on the bobbins as it leaves the hand of the spinner, must be so unwound and laid out as to form 1000 lengths, constituting when laid parallel the warp of the intended cloth. The ancient method was to draw out the warp from the bobbins at full length in an open field; and this is still practised in India and China: but the climate of Europe is too uncertain for such a method, and hence the *warping-frame* was devised. This is a large wooden frame fixed up vertically against a wall, the upright sides being pierced with holes to receive wooden pins, which project sufficiently to receive the clue or group of yarns. The warper, having placed the bobbins of yarn in an adjacent frame, ties the ends of all the threads together, and attaches them to one of the pins; then gathering all the threads in his hand into one clue, and permitting them to slip through the fingers, he walks to the other end of the frame, where he passes the yarns over the fixed pin. He walks from end to end of the frame, attaching the clue of yarns to the pins each time, until he has unwound from the bobbins enough yarn to form the warp. But this method, although still followed in some places, has yielded to the use of the *warping-mill*, a much more convenient piece of apparatus. The bobbins are placed in a frame E (*fig.* 1). The warper, sitting at A, rotates the vertical reel or cylinder B, by means of the wheel C and the rope D. The yarns from all the bobbins, collected together in a group at F, there pass through a sliding piece, which through the intervention of the cord G and the revolving shaft H, rises and falls. By this arrangement it is easy to see that when the handle is turned by the warper, the clue becomes wound spirally on the reel. The diameter of the reel is so regulated, that when the spiral equals the intended length of the warp, the clue of yarns is twisted round pins at I I, and then by a reverse motion of the handle is wound spirally down again; and so on up and down alternately until the grouped clues of yarns constitute a sufficient number for the width of the warp. Certain minor adjustments are at the same time made, to facilitate the subsequent operations of the weaver. The more modern warping-machines we shall have to mention when we come to power-weaving.

Fig. 1.



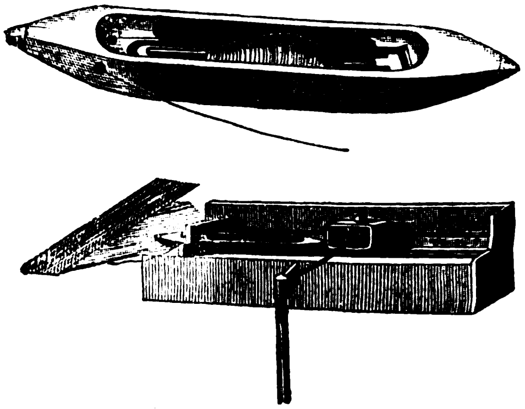
When the warp is completed on the warping-mill, the warper takes it off and winds it on a stick into a ball, preparatory to the process of *beaming*, or winding it on the beam of the loom. The threads, in this latter process, are wound as evenly as possible on the beam; a separator, ravel, or comb being used to lay them parallel, and to spread them out to about the intended width of the cloth. Arrangements are then made for *drawing*, or attaching the warp-threads individually to certain mechanism of the loom. This we may illustrate by *fig.* 2, representing the common loom in its simplest state. The yarn-beam is at A, capable of revolving on its axis, and of allowing its threads to be drawn out in a horizontal layer B. At C are two leaves of heddles or healds, each leaf consisting of a number of strings ranged vertically, attached at bottom to two treadles H H, and at top to a cross-bar. At about the middle of every heddle or string is a loop or eye, through which the warp-yarns are drawn, one through each eye; and the passing of the yarns through these loops constitutes the process of *drawing*. Half of the warp-yarns, that is, every alternate yarn, passes through the loops in one leaf of heddles, and the other half through the other leaf; and as the two leaves are so connected by pulleys that one rises when the other sinks, the warp becomes divided into two portions, one above the other, near the anterior end of the loom. The weaver sits at G, drives the shuttle by means of the handle I, and drives up every successive weft-thread by the batten, lay, or lathe E, suspended from F. However complicated the loom, the principle of action is nearly as here described.

Fig. 2.



There are three movements attending every thread of weft which the weaver throws across the warp. In the first place he presses down one of the two treadles, by which one of the two halves of the warp is depressed, thereby forming a kind of opening called the *shed*. In this shed, at the second movement, he throws the shuttle containing the weft-thread, with sufficient force to drive it across the whole web. Then, at the third movement, he grasps the batten, which is a kind of frame carrying at its lower edge a comb-like piece having as many teeth as there are threads in the warp; and with this he drives up the thread of weft close to those previously thrown. One thread of weft is thus completed, and the weaver proceeds to throw another in a similar way, but in a reverse order, that is, by depressing the left treadle instead of the right, and by throwing the shuttle from left to right, instead of from right to left. In the commonest mode of weaving the shuttle is thrown by both hands alternately; but about a century ago John Kay invented the *fly-shuttle*, in which a string and handle are so placed that the weaver can work the shuttle both ways with one hand. The fly-shuttle is illustrated in CHECK; while *fig.* 3 will show more clearly the mode in which the weft is wound round the spindle or pirn of the shuttle, and the arrangement for driving the shuttle into the open shed of the web. The spindle of the shuttle contains enough weft for several shoots or throws; the weft unwinding as the shuttle travels along, and forming the selvage of the cloth when the shuttle returns in the opposite direction.

Fig. 3.



In cotton and some other fabrics, the warp-yarns must be *dressed* as the weaver proceeds, that is, rubbed over with some kind of vegetable mucilage, such as paste or size, for the purpose of giving them tenacity, of diminishing friction by smoothing down the little hairy filaments of the yarn, and of imparting a smoothness or gloss. In hand-weaving, the weaver suspends his operations from time to time, in order to apply dressing to his warp. He first applies a kind of comb to the warp, to clear away knots and burrs; then lays on the paste with a brush; and lastly dries the paste by a current of air excited by a large fan. The more modern and complete *dressing-machine* we shall have to notice in connection with power-weaving.

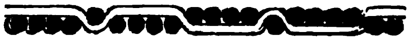
In weaving plain silks, calicoes, and other webs of moderate width, there are two leaves of heddles and two treadles, for dividing the warp into two parcels. In weaving broader webs, such as floor-cloth canvas, the heddles and treadles are equally simple, but more power and dexterity are necessary in throwing the shuttle, since the width of the web is sometimes as much as eight yards. In weaving very narrow webs, such as ribbons, galloons, &c., there would be a waste of power and of time if only one shuttle were thrown across a distance of two or three inches at each movement; and there has consequently been devised a kind of loom called the *engine-loom*, in which several shuttles work several webs at one time in each machine: this has been explained in RIBBON. Various details concerning plain woven goods will be found under COTTON; LINEN; MUSLIN; SILK; WOOLLEN.

Pattern-weaving.—The number of woven webs which can come under the designation of plain-weaving is much smaller than that of those now to be considered. Whenever the warp and weft are of the same colour, and intersect each other in regular order, so as to produce a uniform surface totally divested of pattern, we may deem that *plain-weaving;* but every day's experience shows that pattern, of some kind or other, is a more prevailing characteristic of woven fabrics.

In the first place we may take the case in which all the threads of the warp are of one colour, and all those of the weft another colour: this produces the peculiar effect called *shot* patterns, but involves no new arrangements as to weaving. Next come the two varieties known respectively as *stripes* and *checks.* A stripe is a pattern in which parallel lines run either along or across the warp; while a check is an alternation of rectangles like a chess-board, or, more properly, like the varieties of Scotch plaid. The production of a stripe depends either upon the warper or the weaver; the production of a check depends upon both. If the stripes are of different colours, and extend lengthwise of the cloth, then the warper so disposes the threads of his warp that the two colours shall succeed each other at regular intervals; but if the stripes are of the same colour, but of different quality as to fineness, then the warper uses two qualities of warp in alternate succession. If the stripes extend across the cloth, the warper arranges his threads as for plain-weaving; but the weaver uses two or more shuttles, carrying two or more coloured wefts, and throws the shuttles at regular intervals in succession. If a check is to be produced, the warper first produces his alternation of colours in the warp, and the weaver then throws in wefts of different colours by using two or more shuttles, so that the interlacing of the long stripes with the cross-stripes produces the check, the pattern of which depends on the comparative width of the various stripes. The manner of using the combined shuttles is described under CHECK.

The next to be noticed is the production of the *twill,* a very extensively adepted variety of woven work, since it comprises satin, bombazeen, kerseymere, and numerous other kinds. In the twill, the weft-threads do not pass over and under the warp-threads in regular succession, but pass over one and under two, over one and under three, or over one and under four, six, &c., according to the kind of twill. The effect of this is to produce a kind of diagonal ribbed appearance, on one side of the cloth, and a smooth and glossy appearance on the other, according as the one thread is crossed above or below by the weft. *Fig.* 4 will assist our comprehension of this point. If we suppose the round dots to be sections of successive warp-threads, and the white double line to be one thread of weft, we shall see that the weft passes over four, under one, over four; then under four, over one, under four; and if the specimen were continued, we should see that these cycles of changes succeed each other in regular order. This arrangement furnishes the *twill* for some particular varieties of cloth; and the weaver has thus a kind of numerical formula for diaper, dimity, dornock, damask, bombazeen, satin, kerseymere, &c.; each one having a certain order of succession in which the weft crosses the warp. [BOMBAZEEN; DAMASK; DIAPER.]

Fig. 4.



Now in order to allow the weft to pass under four or more threads at once, some mechanism must be devised for elevating all those four at one movement, or keeping them stationary while every fourth thread is depressed. If the weft always passed under the same four threads, no cloth would be produced, for no reticulation would be made; but the groups of four passed under by one weft-shoot are not the same as those crossed at the next following shoot. Hence more than two leaves of heddles are required, and more than two treadles to work them. There must, in such a case as we have above supposed, be five leaves of heddles, to each of which every fifth warp-thread is attached; and to each of these leaves a treadle is appropriated; so that when one treadle is pressed down, one-fifth of the warp-threads becomes drawn out of the horizontal plane; when another treadle is depressed, another fifth is affected; and so on. The weaver, by the management of his treadles, has the power of raising or depressing four-fifths of his warp-threads, in groups of four each, leaving every fifth thread stationary; and in this state of things he throws his shuttle. By various combinations among his five treadles, he can produce many varieties of movement, which give rise to different kinds of twill.

When, instead of, or in addition to, a twill, the weaver has to produce sprigs, flowers, spots, or any kind of figure, a great increase of complexity occurs. The weft may pass over four and under one at one part of the width of the cloth; over two and under two at another; over one and under four at another—according to the part of the figure which may happen to occur at any particular part of the width of the cloth. Hence the order in which the warp-threads must be depressed or elevated varies continually, and the number of leaves of heddles would become so numerous that the loom could not hold them, nor could the feet of the weaver move the requisite treadles. This difficulty gave rise to the invention of the *draw-loom,* in which strings are so arranged that a boy can draw down the requisite warp-threads preparatory to the movement of the shuttle. The warp-threads pass through eyes or loops in vertical strings, each thread having one string; and these strings are so grouped that the attendant boy, by pulling a handle, draws up all those warp-threads which are necessarily elevated for one particular shoot of weft; and when a different order of succession is required, he pulls another handle. Hence it follows that the arrangement of the strings and handles must be preconcerted with especial reference to one particular pattern; and this is called *cording the loom.* The cording would sometimes take one man three or four months, and would then only serve for one particular pattern. Early in the present century two inventions were made with the view of rendering the draw-loom more automatic. One of these, called the *draw-boy,* not only superseded the necessity of employing a boy to pull the handles, but removed, by the unerring certainty of its operation, all possible chance of mistake in pulling the wrong handle. This was a very ingenious arrangement of mechanism by which a treadle, worked by the foot of the weaver, gave a vibratory motion to a curved lever which drew down some of the warp-threads and elevated others; and the skill consisted in so causing the lever to travel along a rack or toothed bar as to act upon different warp-threads in succession. The draw-boy has been very much employed; while another invention, equally ingenious perhaps, has, from various causes, failed to come into use. This latter was the *automatic carpet-loom* of Mr. Duncan. Here the warp-threads, instead of being elevated and depressed by the handles as in a draw-loom, or by the reciprocating lever as in the draw-boy, were moved by pins inserted in a rotating barrel, the pins being placed in an order of succession according to the pattern to be produced, just as those on the barrel of a street-organ or a musical-box are disposed according to the tune to be played. But the draw-loom, the draw-boy, and the barrel-loom have been alike eclipsed by the exquisite apparatus of M. Jacquard, which is very properly named after the inventor. [JACQUARD APPARATUS.]

Double Weaving.—In all the fabrics hitherto noticed, there is but one layer of threads, formed by the intersection of the weft among the warp, both weft and warp being individually single. But there has long been practised the weaving of a kind of double cloth, composed of two webs, each consisting of separate warp and weft, but both sets interwoven at intervals. The junction of the two webs is formed by passing each of them occasionally through the other, so that each particular part of both is sometimes above and sometimes below. Kidderminster or Scotch carpeting is one of the few kinds of double-fabric now woven in this country; and it will therefore be sufficient for us to refer for details to the article CARPET MANUFACTURE.

Cross Weaving. This term may conveniently be applied to those varieties of woven fabric in which the warp-threads, instead of lying constantly parallel, as in all the cases hitherto noticed, cross over or twist around one another, thus forming a plexus or interlacing independent of that produced by the weft. *Gauze* and *bobbin net* are perhaps the most remarkable examples of this kind of fabric. [GAUZE; LACE MANUFACTURE.]

Chain Weaving.—This is a term usefully applied to a mode of using threads in which a series of loops is formed by a continuous thread, each loop or link being so connected with others as to form a kind of chain; and this chain work may either be worked upon a ground woven at the loom, or may constitute the woven material itself. *Sampler work, Berlin work, sewed muslin work, tambouring, embroidery, tapestry, pillow lace,* and *hosiery,* are all examples, more or less varied, of this chain-weaving. [EMBROIDERY; HOSIERY MANUFACTURE; LACE MANUFACTURE; TAPESTRY.]

Pile Weaving.—If we examine a piece of silk velvet, or any kind of fustian, such as velveteen, moleskin, or doeskin, or a Turkey or Wilton carpet, we shall find that in any or all of these fabrics the warp and weft threads are almost concealed by a kind of down, nap, or pile, which imparts a peculiarly soft and smooth texture to them. It may seem strange to class together such very different materials as silk velvet, fustian, and Turkey carpeting; but the classification is strictly correct, because all of them owe their characteristic beauty to the downy surface which they present. Fustians are in fact a kind of cotton velvet, as Turkey carpeting is a woollen velvet. The weaving of these pile-fabrics, so far as regards the decussation of the warp and weft threads by means of the shuttle, resembles that of plain fabrics, or of pattern-fabrics, according to the nature of the design. But there is, besides the warp and weft properly so called, another kind of warp, whose threads are left standing in loops above the general surface till cut, and the cutting of which constitutes the pile. In some kinds of fustians the pile is cut so as to give a smooth velvet surface; while in other kinds it is cut into parallel cords, forming corduroy and such like fabrics. The cutting used formerly to be done by peculiarly shaped knives held in the hand; but some very ingenious machines have been contrived for effecting it more quickly and correctly. For the application of this peculiar manufacture to different fabrics, see CARPET; FUSTIAN; VELVET.

Power-Weaving.—In all the kinds of weaving hitherto noticed, whether of plain goods, figured goods, double cloth, bobbin-net, stockings, or velvet fabrics, we have uniformly spoken of the weaving-machine as being worked by hand, or rather by hand and foot, for the treadle is an almost invariable component of such a machine. We have however now briefly to notice the important steps by which the steam-engine has been brought to bear on this department of industry.

In the 'Philosophical Transactions' for 1678, a loom, invented by

M. de Gennes, is described as "a new engine to make linen cloth without the aid of an artificer," by applying water-power as the moving force. The advantages are thus enumerated: "1, That one mill alone will set ten or twelve of these looms at work; 2, the cloth may be made of what breadth you please, or at least much broader than any which has been hitherto made; 3, there will be fewer knots in the cloth, since the threads will not break so fast as in other looms, because the shuttle that breaks the greater part can never touch them. In short, the work will be carried on quicker and at less expense, since, instead of several workmen, which are required in making up of very large cloths, one boy will serve to tie the threads of several looms as fast as they break, and to order the quills in the shuttle." This description remarkably well expresses the excellences of the power-loom of the present day; but we have no evidence that De Gennes' machine ever came into use. At various times during the last century M. Dolignon, M. Vaucanson, Mr. Austin, and Mr. Miller contrived looms which were to be worked by a winch, by water-power, or by some contrivance more expeditious than the common hand-weaving. The first power-loom for weaving cotton fabrics was put up by Mr. Austin in the factory of Mr. Monteith, near Glasgow, in 1798; but before that time another machine had been invented, whose history is curious and interesting.

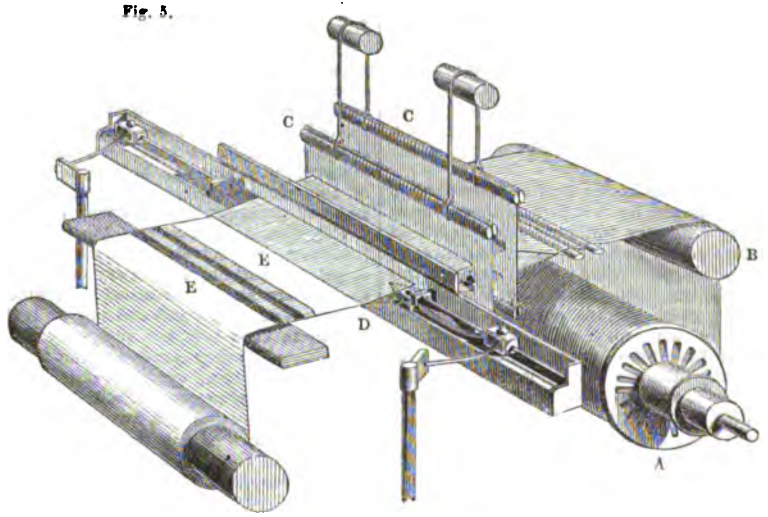
The Rev. Dr. Cartwright, brother of the late Major Cartwright, happened, in 1784, to be in conversation with some gentlemen, concerning Arkwright's spinning machinery. It was observed that, so soon as Arkwright's patent expired, so many mills would be erected, and so much cotton spun, that hands would not be found to weave it. Cartwright remarked that Arkwright must, in that case, invent weaving machinery; and the idea, thus suggested by himself, seems to have taken hold of his mind; for he soon afterwards endeavoured to form a machine which should imitate the three movements in weaving. He succeeded so far as to produce a machine, which he patented in 1785; and another, for which a patent was obtained in 1787. He tried to establish a power-loom weaving factory at Doncaster, but failed: Messrs. Grimshaw also endeavoured to set Cartwright's machines at work at Manchester, but similarly failed from various causes; and, after many years of labour, many patents, and an expenditure of 40,000*l.*, Dr. Cartwright was compelled, in 1808, to ask for a grant from Parliament as a return for his losses and exertions. Parliament awarded him 10,000*l.* One cause which thus delayed the adoption of power-looms was the necessity for stopping the machine frequently, in order to dress the warp as it unrolled from the beam, which operation required a man to be employed for each loom, so that there was no saving of expense. In the year 1802, Mr. Radcliffe, a cotton manufacturer of Stockport, aided by a workman, Thomas Johnson, made many contrivances with a view to remedy this inconvenience, and at length produced the admirable *dressing-machine* of modern factories, by which the warp is dressed before it goes into the loom. At a subsequent period Mr. Horrocks and Mr. Marsland, both of Stockport, made other improvements, which brought the steam-engine fairly into use for weaving operations, and thus power-looms became established. Still more recently, Mr. Roberts, of the firm of Sharp and Roberts, Manchester, brought the power-loom to a state of high perfection; and every year adds more and more to the number of such looms employed in manufacturing districts.

The application of the power-loom renders necessary the employment of other machines likewise, to effect those preparatory operations which, in hand-loom weaving, are effected by very simple means. If we take a piece of calico as the representative of plain fabrics generally, the mode of proceeding in power-loom factories may be shortly sketched as follows:—

The *warping-frame*, instead of being employed on the same principle as the warping-mill sketched in a former page, is so arranged as to be worked by steam-power. Several bobbins, arranged with their axes parallel and horizontal, in a compartment at one end of the frame, yield the yarn which is to be collected into a warp. The yarns, proceeding from the bobbins, pass under some rollers and over others, until all are brought into a parallel layer, a comb of fine wires being employed to separate the yarns equidistantly. The yarns are then collected and coiled on a cylindrical beam, which is removed from the *warping-frame*, and transferred to the *dressing-machine*. This latter is a large piece of mechanism, by which the contents of eight rollers from the warping-frame are collected on one roller or beam, which is to form the warp-beam of the loom; and in their passage the yarn-threads are coated with the paste or mucilage-dressing, and dried. Four of the rollers are placed at one end of the machine, and four at the other; and the yarns, proceeding from thence, pass between rollers, of which the lowermost dips into the paste, and becomes thus coated with it; they then pass under and over brushes, by which the paste is rubbed into the fibres; then over a steam-heated copper box, by which they are dried; and, lastly, are wound on the warp-beam.

The preparation of the warp in the loom, comprising what are called the *drawing* and *mounting*, is more simple for the power-loom than in the hand-loom, but is still somewhat intricate. When, however, this is effected, steam-power does all the rest: it forms the shed or division of the warp into two parts; it throws the shuttle; it drives up the weft with the batten; it unwinds the warp from the warp-roller; and winds the woven material on the cloth-roller. Part of these operations may be illustrated by *fig.* 6, in which some of the mechanism is omitted to render the rest more clear. The warp, unwinding from the beam A, and bending round the roller B, passes through the two leaves of heddles C C, by which the shed is formed for receiving the shuttle at D; and after the action of the batten (not here shown) the finished cloth E results.

Fig. 5.



The pressing, finishing, dressing, &c., which the woven goods receive, whether woven by the power-loom or the hand-loom, depend, of course, on the nature of the fabric. One of the most important of these processes, by which the plain goods become diversified with ornament, is described under CALICO PRINTING.

Weaving, like all other parts of textile manufacture, has been marked by the introduction of many new forms of apparatus within the last few years. We will briefly mention the names of a few, as samples of the whole. Messrs. Tatton and Hodgkinson have a new small-ware loom, for weaving all kinds of narrow work, such as ribbons, galloons, chintz-lace, bed-lace, carpet-binding, tapes, &c. Mr. Somerville has introduced a new form of steam-power loom for twill, diaper, and worsted goods, especially intended for varying the effects in the same web by varying the shed-action. Mr. Macfarlane, of Comrie, introduced an arrangement in 1858 for enabling a loom to supply its own shuttle with fresh warp when exhausted or broken, and also to stop itself when any definite number of warp-threads have become broken. Mr. Ingram, of Bradford, patented in 1860 mechanism for obtaining continuous action in looms; that is, a method of supplying the loom with weft without stopping it to change the bobbin or cop; or of giving an additional supply of weft while the loom is in action, and whether the weft be all used up or only broken. Mr. Schwabe has invented an ingenious way of weaving *flounced* dresses. To effect this there is an additional warp-beam laid beside the usual one: the warp from this beam is brought into use in producing the body of the dress; but when a fringe, cording, &c., is wanted for a flounce, a portion of the other warp is brought forward by itself; or else this second warp may only be used in the flounce, and cut off at regular intervals.

Concerning the application of the arts of design to weaving, Professor Willis, in a report on the Paris Exhibition of 1855, gives an interesting account of the duties of a French functionary called the 'Professeur de la Théorie des Fabrications':—"This is a class of instruction which appears to be peculiar to Lyons, and to the want of which our deficiency in that respect may greatly be attributed. Their business is not to teach artistic drawing as a branch of fine art, but to teach the connection of design with the machinery which must be employed to realise it; to explain the entire construction and management of the looms, the mode of mounting and adjusting them, the different tissues or textures of which they are capable; the application of these to the respective parts of a given design, either as grounds or as means of bringing out details with the greatest effect, and at the same time with the necessary economy—seeing that contrast and variety of textures in the different details of a woven picture occupy the place of the painter's *handling* in works of fine art. A design may manifestly be exceedingly beautiful in itself as a work of art, but wholly inapplicable to weaving. No artist, therefore, can be qualified to make a weaver's design which shall combine in itself the beauty of art, applicable to produce effective results when translated from oil-paint or water-colours into silk or worsted, unless he be familiar with the mechanism of the looms in their infinite variety, with their practical adjustment, and with the characteristic surface-effects of the different tissues. Every designer, in short, should be able to put his own designs into the loom. Accordingly, artists, after having studied in the School of Design at Lyons, put themselves in the next place under the instruction of one of these so-called Professors of the Theory of Fabrics, for six months or more, to learn the application of the design to the machine. This is the system which has enabled the manufacturers of that city to produce the magnificent and beautiful specimens which were displayed in the galleries of the French Exhibition."

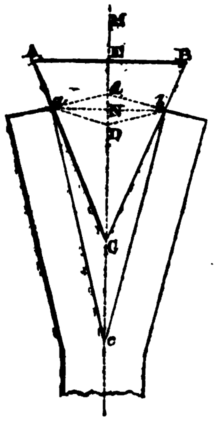
Bonelli's Electric Loom.—There is one modern invention in weaving of so remarkable a character as to deserve special notice. The theory is sound, although there may not at present be obtained a mastery over the mechanical details for carrying it out. M. Bonelli's Electric Loom has been described by Dr. Faraday at the Royal Institution, and by Mr. Le Neve Foster at the Society of Arts. The following is a slight outline of its origin and nature. In 1844 the Society of Arts prize was given to Mr. Riding for certain improvements in the Jacquard Apparatus; he employed an index-machine, something like Duncan's barrel described in an earlier paragraph, with shifting pegs for changing the patterns, the pegs acting in connection with wires in the apparatus. In later years other improvements were introduced, many of which have been noticed in Jacquard Apparatus. This subject attracted the attention of M. Bonelli, an Italian Civil Engineer, and Director General of the Sardinian telegraphs. He employed a long period of time in developing the theory and details of an electric apparatus which might dispense with the cards necessary in the Jacquard looms for weaving figured goods; and brought his machine to England in 1859. Bonelli's apparatus will suit any existing looms. It consists principally of an endless band of paper covered with tinfoil. The design or pattern is painted on the tinfoil with a brush and black varnish. The band passes under a series of thin metal teeth, all in connection with a galvanic battery. Whenever the foil touches a tooth a current passes through it, and thence through coils of wire surrounding small bars of soft iron, making them temporary magnets; but whenever the varnish touches a tooth, no such current is produced. Numerous small rods are placed opposite the ends of the small bar magnets; they pass horizontally to and fro, through a plate in front of a moveable frame. When any of the bars are actively magnetic, they retain or attract the rods when in contact with them. When the frame is swung or moved so as to bring the rods in contact with the bars, some are drawn a little distance through the holes in the plate, while the others are not so affected: according as the particular bars are at that moment in a magnetic state or not. The rods are like pistons, for each exactly fits one hole without tightness; and thus it happens that, when the frame recedes, some of the holes are open, while others are filled with the rods. The plate acts the part of a Jacquard card; each movement of the frame opens a distinct series of holes, and thus changes the pattern. A treadle moves the frame, at each throw of the shuttle. When the design is to be in several colours, it is in like manner painted on the tinfoil; but each separate colour, by removing a very thin strip of foil at the margin, is insulated from its neighbouring colour. All the pieces of foil thus insulated, each representing one colour or shade, are connected by small strips of tinfoil, which pierce through the paper and are fastened at the back, whence they are conducted to another strip of tinfoil which runs along the edge of the band: there being as many such strips of tinfoil as there are colours. Thus each special colour of the design, in all its parts, is connected by a conductor with its own separate strip of tinfoil. By bringing the wire from the galvanic battery successively into contact with the several strips, a current of electricity may be made to pass in succession through the several parts of the design representing the several colours. Thus, assuming four colours; there would be four strips of tinfoil running the length of the band, insulated one from another, each in connection with its own peculiar colour only. At any given moment, thin plates of metal resting on the design would touch it in a line which, as it passes over the *width* of the design, would run through all or any one of the colours; but the current would pass only through those plates which rest on the one colour represented by the strip connected at that moment with the pole of the battery. The shifting of the band does not in this case take place with every throw of the shuttle, but after an interval depending on the number of colours.

Such is Bonelli's electric loom. The inventor states, that two cells of a small Bunsen's battery will suffice, consuming one pennyworth of chemicals per day. The cost of the whole apparatus is about 20*l.* An elaborate damask design will sometimes require, on the Jacquard system 4000 cards and 400 wires, which would cost 24*l.*, and five weeks of a man's labour to set up. On the Bonelli system, we are told, the expense would be 6*l.*, and the time one week. A Jacquard design has been known to take 20,000 cards, costing 150*l.*, and an amount of labour equal to one whole year of one man's time; the figures on the Bonelli system would be 26*l.* and one month. Several advantages are claimed for the system:—1. The great facility with which, in a very short time, and with precision, reductions of the design may be obtained on the fabric by means of the varying velocity with which the design may be passed under the teeth. 2. That without damaging the mounting of the loom or the design, fabrics thinner or thicker may be produced by changing the number of the weft, and making a corresponding change in the movement of the design. 3. The loom and its mounting remaining unchanged, the design may be changed in a few minutes by the substitution of another metallised paper having a different pattern. 4. The power of getting rid of any part of the design, if required, and of modifying it. The validity of these claims remains for the future to show.

WEB. [Weaving.]

WEDGE, in Mechanics, is a prism of wood or metal whose base is a triangle: it is employed to remove two objects from one another laterally, or to rend asunder the parts of a body; an edge which is parallel to the geometrical axis of the prism being introduced between the objects, or parts of the body, and the whole wedge being then driven forward by a percussive force, as the stroke of a hammer. The nature of percussive force, and of the resistance which a yielding material opposes to the motion of the wedge being, however, imperfectly known, it is usual to consider the motive-power and the resistance as simple pressures, or weights, in estimating the conditions of equilibrium when a wedge is employed as a machine.

Let ABC represent the section of a wedge perpendicularly to the mathematical axis; and for simplicity, suppose this section to be an isosceles triangle. The plane passing though AB, perpendicular to ABC and to the paper, is called the head or back of the wedge: the planes passing through AC and BC perpendicular to the paper are called the sides; and their line of section, passing through C, is called the edge.



The motive-power is applied to the head of the wedge; and may be supposed to act in the direction MC perpendicularly to that plane, and passing through C in the edge. Let the material which is to be rent asunder be in contact with the sides of the wedge in lines passing through *a* and *b* perpendicularly to the paper; and let the two parts yield as if they were capable of turning about some point *c* in the direction of MC, produced if necessary: then it is evident that the effect of the wedge will be the same as if a section of the latter, perpendicularly to the axis, were *abc*. Imagine *ad*, *bd* to be drawn perpendicularly to *ac* and *bc*; then those lines will meet at a certain point, as *d*, in the line MC: imagine also the parallelogram *adb*D of forces to be constructed; then *d*D or 2*d*N will represent the motive force, and *da* or *db* the pressure which that force exerts at *a* or *b* perpendicularly to *ac* and *bc*. Let P represent the motive force, and R the pressure at *a* or *b*; then, in a state of equilibrium, the latter will represent the reaction of the material in the direction *ad* or *bd*; and we have

$$P : R :: 2dN : da.$$

But the triangle aNd is similar to cNa; therefore

$$dN : da :: aN : ac,$$

and consequently $P : R :: 2aN\,(=ab) : ac$.

The position of the point c where the separation of the material is supposed to take place varies for different materials, and can only be estimated, or found from experiment: if it were supposed to coincide with C, we should have

$$P : R :: 2aN : aC;$$

or by similar triangles abC, ABC,

$$P : R :: AB : AC.$$

If the force of the wedge at the points a or b were to be estimated in the direction Na or Nb; as when it is required, neglecting friction, to find the force with which a given pressure P in the direction MC, on the head of the wedge, would make a body at a or b slide in a direction perpendicular to MC: then, R' representing that force, and c coinciding with C, or ad being now perpendicular to AC, we should have

$$P : R' :: 2dN : Na, \text{ or as } 2aN \text{ to } NC, \text{ or as } AB \text{ to } EC.$$

The point c still coinciding with C, let θ represent the angle ACE, or half the angle of the wedge: then

$$\frac{aN}{aC} = \sin\theta, \text{ or } \frac{AB}{AC} = 2\sin\theta;$$

$$\text{also} \quad AB : EC :: 2\sin\theta : \cos\theta:$$

it follows, radius being unity, that

$$P : R :: 2\sin\theta : 1, \text{ or } P = 2R\sin\theta;$$
$$\text{also } P : R' :: 2\sin\theta : \cos\theta, \text{ or } P = 2R'\tan\theta;$$

where R and R' represent the pressures perpendicular to AC and to EC respectively.

If it were required to find an equation for the motion of a wedge when acted upon by a force of percussion, a process corresponding to that which follows must be employed.

Let, as before, ABC be a section of the wedge, which may be supposed of iron: let it be introduced between the parts of a body which can yield only in a lateral direction; and let it be driven by a mass of iron falling upon it from a point at some given height above. Both the wedge and the hammer, or falling body, must be understood to be elastic; and it will be convenient to represent the latter by a parallelopiped of iron whose base is equal to the rectangular head of the wedge: let the height of such solid be represented by P, and let the space through which it is supposed to fall be represented by h; then, by dynamics, $2gh$ will be equal to the square of the velocity of impact. In like manner, let the friction of the wedge, estimated in a direction parallel to CM, be represented by the weight of a parallelopiped of iron whose base is the rectangular head of the wedge; and let the height of such parallelopiped be represented by Q.

When the collision takes place, both the falling body and the wedge will be compressed in the direction of their length. Let the linear contraction of P be represented by p, and that of the wedge, supposed at present immoveable, by q (both p and q coinciding in direction with MC). Then if ϵ represent the modulus of elasticity (or the height of a vertical column of iron, having a base equal to the head of the wedge, whose weight would, by the compression it causes, reduce the height P or Q of the supposed masses of iron to zero) and the forces of compression be assumed proportional to the contractions which they produce, we shall have $\frac{\epsilon p}{P}$ and $\frac{\epsilon q}{Q}$ for the forces by which the falling body and the wedge are respectively compressed in consequence of the collision; or the forces by which they tend to recover their original state: let these be represented by mp and nq respectively; or, in terms of the force of gravity, by mgp and ngq. Then ngq will represent the motive force by which the movement of the falling body is resisted after the impact, or $-\frac{ngp}{P}$ will represent the retardative force against that body.

But from the equality of action and re-action we have $mp = nq$; whence $p = \frac{nq}{m}$, and $p + q$, or the sum of the compressions, is equal to $\frac{n+m}{m}q$: let this be represented by s; then $q = \frac{ms}{n+m}$ and $\frac{ngq}{P} = \frac{mngs}{(n+m)P}$. Now, by dynamics, accelerative or retardative force is represented by $v\frac{dv}{ds}$, v here being the velocity of the falling body at any time t between the instant of impact and that at which its motion is extinguished by the resistance: therefore

$$\frac{vdv}{ds} = -\frac{mngs}{(n+m)P},$$

and integrating, V representing the velocity at the instant of impact at which time $s = 0$,

$$v^2 = V^2 - \frac{mng}{(m+n)P}s^2.$$

But when the wedge begins to move, the friction is equal to the force by which the falling body is compressed; therefore, making Q equal to $\frac{mns}{n+m}$ $(=nq)$ we have $s = \frac{(n+m)Q}{nm}$; which being substituted in the above equation, we have

$$v^2 = V^2 - \frac{(n+m)gQ^2}{mnP}.$$

Now the wedge being uniformly resisted by friction, while moving in consequence of the impact, the retardative force f, expressed in times of gravity, will be $\frac{gQ}{P+W}$, W representing the weight of the wedge in terms homologous to P. Therefore since, by dynamics, $s = \frac{v^2}{2f}$; if we represent the space through which the wedge moves in the direction MC by z, we have, on substituting for v^2 and f their values, and for V^2 putting its equivalent $2gh$, where h is the height due to the velocity V,

$$z = (P + W)\,.\left(\frac{h}{Q} - \frac{(m+n)Q}{2mngP}\right)$$

The values of m and n, that is, of $\frac{\epsilon}{P}$ and $\frac{\epsilon}{Q}$, may be found, since ϵ, the modulus for iron, is known to be about 10,000,000 feet; and consequently the relation between z and Q can be determined in numbers.

WEDNESDAY. [WEEK.]

WEEDS. Every plant which grows in a field other than that of which the seed has been sown by the husbandman is a weed, and inasmuch as it interferes with the intended crop, should be carefully eradicated. One of the principal uses of summer fallows is to destroy the weeds, which come up in spring, and which would shed their seeds in summer, if they were not destroyed before the seeds ripen. When roots are sown in drills, and carefully hoed, they produce the same cleansing effect, and supersede the fallow; but in heavy loams which have been neglected and overrun with weeds, a clean fallow is sometimes indispensable before any improved method can be adopted. When a farmer enters on lands which are in a foul state, it is the cheapest way, in the end, to sacrifice a crop, and thoroughly purge his fields from weeds, especially those which have vivacious roots, and cannot be extirpated by simple ploughing. The mode of doing this must depend on the nature and duration of the weeds, whether their roots are perennial or die off after the plant has borne seed. Annual weeds are most readily extirpated by repeated harrowings, by which the seeds are brought within the influence of the atmosphere, and when they have fairly vegetated may be buried or rooted out, and by exposing their roots to the influence of a hot sun they are effectually destroyed. The seeds of annual weeds are chiefly brought on the land in the manure which is made in the yards, where the cattle fed on hay or straw swallow the seeds, which pass through them undigested. They are also largely sown by the farmer himself in foul seed which he buys of the seedsman.

One of the great advantages of straw, of artificial manures, and of composts made with human excrements mixed with earths and mineral substances, is that they introduce no weeds into the soil. It is reported that in China, where the dung of cattle is little used, in comparison with human excrements, no weeds are to be found in the fields; and if more attention were paid to the preservation of this highly-enriching manure, and its proper application to the soil, much expense would be saved which is now unavoidably incurred in destroying weeds. Feeding sheep on roots and corn, while they are folded on the land, is another mode of manuring a field without introducing weeds, especially if no hay is given them, except clover-hay of the second crop, which is generally most free from the seeds of weeds.

Perennial weeds, such as various thistles, docks, &c., are very difficult to eradicate, as the roots strike deep in the ground, and throw up fresh shoots every year. The most effectual mode of destroying them is to draw them whenever the stem is grown sufficiently to give a good hold of the crown of the root.

Besides the common couch grass, *Triticum repens*, which is the pest of farmers on light soils, there are a variety of plants which spread both by the roots and by creeping along the surface. Of this kind are the different sorts of *quitches*, as they are provincially called, which grow in wet soils. The only mode of extirpating these last is draining and careful tillage. The most effectual means of destroying common couch is by the fork. If, after the ground has been once ploughed, it be forked up carefully in dry weather, and the tufts of couch with their roots be exposed to the hot sun, they may be raked off and burnt.

There are many other weeds, both in arable and pasture land, which indicate slovenly culture, and which disappear on careful cultivation; such are briars, furze, broom, and rushes; the last being a well-known sign of superabundant moisture, and only to be destroyed by under-draining. The whole process of cultivation is a continual struggle between the farmer and the weeds natural to the soil he cultivates. The sooner he subdues them entirely, the less will be his subsequent trouble; and the perfection of agriculture is to produce crops of such vegetables as are useful and profitable, and are suited to the soil which is cultivated, while all others are excluded which might interfere with the crops to be raised. The almost universal adoption of the system of drilling and hoeing the crops, tends greatly to the destruction of useless plants on arable land; much yet may be done by way of improving the produce of meadows and pastures by the destruction of all noxious and useless plants, and the introduction of those which are nutritious and improve the herbage, whether depastured or made into hay; and nothing is so likely to do so as a good system of alternate husbandry, where the best grasses are cultivated as carefully as the plants which are immediately applied to the food of man.

Annual and biennial weeds are easily got rid of in comparison with those which have perennial roots, and some of which increase the faster the more the roots are divided. It may be proper to observe that too little attention is paid to the weeds in our upland meadows and pastures, many of which are detrimental when they are eaten for want of better food. Of this kind are butter-cups, which, where the cows are forced by hunger to eat them, may be very injurious to their health and to the production of good milk. As these plants have strong perennial roots, they take possession of rich moist soils to the exclusion of good grasses. When not very abundant the plants may be weeded out by means of a sharp spud or hoe, and the expense will be well repaid in the quality of the hay or pasture.

WEEK. This well-known period of seven days, now universally adopted over the Christian and Mohammedan world, appears to be of Hebrew or Chaldæan origin. It has been commonly regarded as a memorial of the creation of the world, according to the Mosaic account, in that space of time; but it is besides the most obvious and convenient division of the lunar or natural month; and it is also more nearly than any other short term would be, an aliquot part of the solar year of 365 days; so that its commodiousness in these two ways would seem to have been sufficient to recommend its adoption.

Dion Cassius attributes the invention of the week to the Egyptians, from whom he seems to say it was borrowed in later times by the Greeks and other nations ('Hist. Rom.,' xxxvii. 18, 19, and the note in Reimar's edition). It is certain that the week was unknown to the Greeks of the classical ages, and also to the Romans, till it was gradually adopted, along with Christianity, under the later emperors.

The curious passage we have referred to in Dion Cassius is the source of all that is known as to the origin of the names that have been given to the days of the week. The Ptolemaic arrangement of the heavenly bodies, according to their distances from the earth, is in this order:—Saturn, Jupiter, Mars, the Sun, Venus, Mercury, the Moon (Saturn being the most distant); and it was a principle of the ancient astrology that these planets presided in this succession over the hours of the day. Upon this notion, if the first hour be assigned to Saturn, it will be found that the 25th (or first hour of the second day) will fall to the Sun; the 49th (or first of the third day) to the Moon; the 73rd (or first of the fourth day) to Mars; the 97th (or first of the fifth day) to Mercury; the 121st (or first of the sixth day) to Jupiter; and the 145th (or first of the seventh day) to Venus. *Dies Saturni* (the day of Saturn), *Dies Solis* (the day of the Sun), &c., are accordingly the Latin designations that have been given to the days of the week; and from these have been formed the modern names used in different countries either by literal translation (in the Italian, Spanish, French, and other languages of the Latin stock), or (in the Teutonic tongues) by the substitution, in some cases, for the classical god of the corresponding deity of northern paganism. Thus, the deity of the Old Saxons most resembling Mars, being held to be Tiw, or Tiu, the day of Mars was called by them, after their conversion to Christianity, Tiwes daeg, whence our Tuesday (and probably also the modern German Dienstag); for a similar reason the day of Mercury received the name of Wodnes daeg (that is, Woden's day), whence our Wednesday (and the old German Odinstag, for which Mittwoche, "Mid-week," is now used); the day of Jupiter, Thunres daeg, or Thor's day (whence our Thursday, and the modern German Donnerstag); and the day of Venus, Frige daeg, or Friga's day (whence our Friday).

Dion Cassius, however, further states that the planetary theory from which the denominations of the days of the week have thus been derived is itself founded upon the doctrine of musical intervals. A highly curious exposition of this idea has been given by the Abbé Roussier, in a Memoir on the Music of the Ancients, printed in the 'Mémoires de Trévoux,' for November and December, 1770, and August, 1771.

It is a remarkable fact that the week of seven days is not only a recognised space of time in the ancient Brahminical astronomy, but that the days (beginning with Soucravaram, "the day of Venus," or our Friday) are named in succession after the same planets or heavenly bodies as among the Greeks and Latins. Upon this subject see Bailly's 'Astronomie Indienne et Orientale," and various papers by Mr. Colebrooke and others in the 'Asiatic Researches.' The subject of the week is also discussed by Bohlen, 'Das Alte Indien,' ii. 214.

WEHRGELD or **WEHRE** (in Latin "Werigeldum," and in some cases "Compositio"), was a kind of fine for manslaughter, wounds, &c., in use among the ancient Teutonic nations, by paying which the offender, if a freeman, got rid of every further obligation or punishment. The serf or unfree had no right to wehrgeld; but by a law of the emperor Henry II. (1022) the lord of the serf had a claim against the slayer. The punishment of death was almost unknown among the Teutonic nations, and was never inflicted for crimes against individuals, but only for crimes and misdemeanours by which the community as such was injured. Tacitus ('Germania,' 12) says that traitors and deserters were hanged on trees, and that cowards and such as were of infamous lives (*corpore infames*) were smothered in marshes; hurdles were thrown over them, by which their bodies were kept down. Several bodies of Germans who were buried in that way, with the hurdles still over them, have been found in the great marshes of Northern Germany. It is very likely that death inflicted for such crimes was less a punishment than a means of getting rid of persons the sight of whom was a disgrace to the community, and for whom there were no prisons. Crimes committed by one individual against another were considered not directly to concern the community. The wounded man, or the relations of him who had been slain, pursued the culprit till they found him ready to satisfy their vengeance by giving them a certain number of cattle and arms. (Tacitus, *ib.*, 21.) If the parties belonged to different communities, the consequence was a feud between them and their adherents, no community having the slightest authority over another; but if the parties belonged to the same community, the matter was soon settled. The plaintiff called the offender before the community, and if the defendant was found guilty, he was sentenced to pay a certain fine, the wehrgeld or wehre. If the defendant would not or could not pay, his relations were bound to pay for him; the father paid for his children, the master for his serfs, and he who received a stranger in his house was liable for the misconduct of his guest. The plaintiff was not obliged to summon the offender before the meeting: he could pursue his cause with his sword, and thus compel the defender to pay the wehrgeld, which was always proportionate to the offence. If the cause was brought before the community, the plaintiff only received part of the wehrgeld; the community, or the king, when there was any, received the other part. (Tacitus, *ib.*, 12.) The part paid to the community must be considered as a fine for the breach of peace, and the consequence of the reciprocal obligation of the members of the community to maintain order. If the wehrgeld were not paid, the right of taking personal revenge was resumed. Laws therefore were passed enabling the community to enforce a wehrgeld even when the defaulter was unable or refused to pay.

We learn from the written laws of the Teutonic nations that the wehrgeld was for various crimes and misdemeanours, such as murder, manslaughter, infliction of wounds, and grievous bodily harm, robbery, theft, incendiarism, plagiary, rape, sodomy, verbal and real injuries, and several others, such as the violation of a grave ('Lex Salica,' tit. xvii.), by which is understood not only the injury done to the tomb, such as taking the tombstone from one grave and putting it on another, but also stealing a dead body, or its clothes and ornaments. The general Latin name for the fine paid for such crimes is "compositio;" wehrgeld designating merely the fine for a crime committed against the person of a freeman. The amount of the fine was in proportion to the nature of the crime, to the loss of property or damage resulting from it, and it varied according to the rank of the injured person as well as of the offender. In case of theft or damage, the fine did not exclude either the restitution of the stolen object or of the damaged thing, if possible. In England the laws relating to wehrgeld received many modifications from Alfred downward.

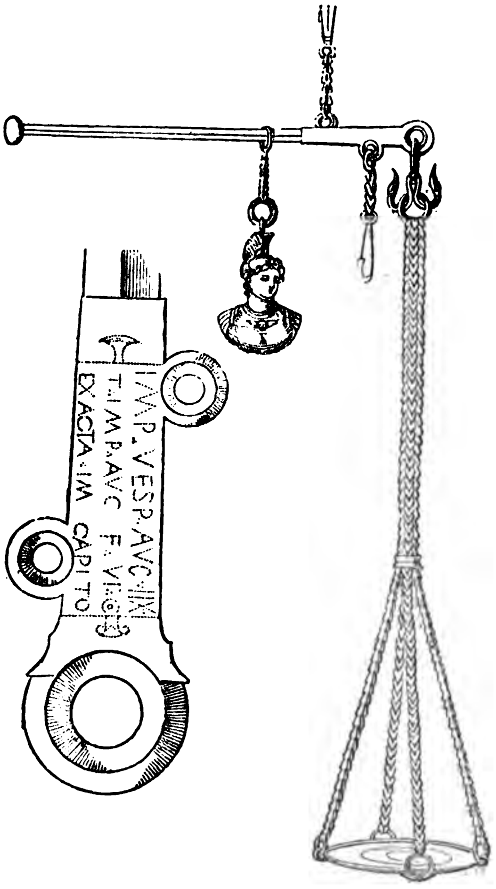
The wehrgeld was not the same among the different Teutonic tribes, as may be seen by a comparison of their laws. The laws of the Anglo-Saxons deserve particular attention. Mr. Kemble calculates that in Kent the wehrgeld of the noble was 360 shillings, and of the freeman (or ceorl) 180 shillings. In Northumberland it seems to have been somewhat higher. In Wessex that of the freeman was 200 shillings and the noble 1200. The clergy were rated high—an archbishop with a prince, a bishop with an ealderman.

(Eichhorn, *Deutsche Staats und Reichts Geschichte*; Kemble, *Saxons in England*.)

WEIGHING-MACHINE is any contrivance by which the weight of an object may be ascertained. Under BALANCE the principles of the machines by which materials of comparatively small magnitude are weighed are explained. The scales with equal arms and equipoised weights require no further elucidation; but a short notice may be given of some others. The *steelyard* is a kind of balance or weighing-machine, consisting of a lever of unequal arms. The most common kind of steelyard, which is often called the Roman balance, is a lever of the first order, and is used by suspending the article to be weighed from the end of the shorter arm, and sliding a determinate weight along the longer arm, to a greater or less distance from the fulcrum, until the instrument remains in equilibrium in an horizontal position; the weight of the substance attached to the short arm of the lever being indicated by observing the position of the moveable balance-weight with respect to a graduated scale marked upon the long arm of the steelyard. In the common steelyard a hook or hooks are usually suspended from the short arm, to hold the article the weight of which is to be ascertained; but sometimes a scale-plate or dish suspended by chains is added. The moveable weight is commonly attached to a ring, the form of which enables it to rest in notches cut on the upper edge of the steelyard, corresponding with the graduations engraved on its side. A ring or hook is also attached to the fulcrum, so that the instrument may be conveniently hung upon a fixed support, or if small, held in the hand; and a vertical index or pointer, similar to that attached to the beam of common scales, is sometimes added. The fulcrum, and the axis from which the weight is suspended, should, when much nicety is required, be provided with knife edges or bearings resembling those used in other lever-balances. Many steelyards are supplied with a second fulcrum; the two being placed at different distances from the point to which the hook or scale is attached, and having their respective pointers and suspending-hooks on opposite sides of the lever, or rather, when held in the position for use, one above and the other below it, as shown in the following cut of an ancient Roman steelyard. In using a steelyard of this kind, capable of weighing from one to sixty pounds, the fulcrum which is nearest to the middle is used if the article be under fifteen pounds; while if it exceed that weight, the instrument must be inverted, and suspended from the fulcrum which divides the lever most unequally.

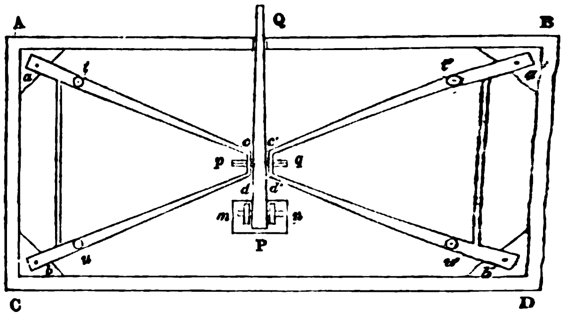
Several ingenious bent-lever balances have been contrived, some of which, from the circumstance of the levers being of unequal arms, resemble the steelyard in principle; and various modifications of the steelyard have been invented for delicate scientific purposes, or for adapting it to the purpose of weighing very heavy bodies. Of the latter class is that which is employed usually at the toll-gates on roads for the purpose of determining the weights of laden carriages. In order to prevent the roads from being too much cut up, the burdens allowed to be conveyed along them by carts or waggons are made to depend on the breadth of the wheels; and a fine is imposed for any excess above the regulated quantity.

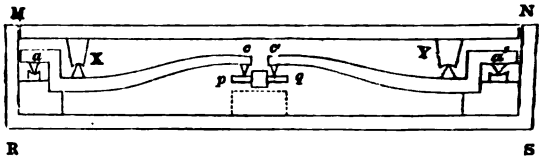
The usual weighing-machine may be described, in a general way, as a platform sunk on a level with the road, and made to rest at four points on a double lever of the second kind. The extremities of the arms of these levers rest upon a third lever, which may be of the first or second kind; and this last lever may either serve as a steelyard, or may be connected with one arm of an ordinary balance, or with the extremity of a steelyard.



Ancient Roman steelyard, found at Pompeii, with part of the beam and inscription on a larger scale.

But to be more particular, let A B C D be the plan of a rectangular pit sunk in the ground, from 8 to 12 feet long, 6 feet broad, and about 2 feet deep, the sides and bottom being lined with brickwork or iron, and let M N R S represent a longitudinal section of the pit perpendicularly to the ground: *a b c d*, *a′b′c′d′* are two trapezoidal frames of iron acting as levers; and each of the side bars, as *ac* or *bd*, has, in the vertical position, the form which is represented by *ac*, *a′c′* in the section. At each extremity *a*, *b*, *a′*, *b′*, in the plan, the frames have a conical steel point, which appears at *a*, *a′* in the section; this rests in a hemispherical cavity made in a die or cylinder of the same metal, which is either attached to the iron-work forming the sides of the pit, or is supported on a block of stone sunk in the ground at each of the four interior angles; and under the shorter side, *cd* or *c′d′*, of each frame there is a wedge-like prism of tempered steel, having its edge parallel to that side. The ends of these prisms appear at *c* and *c′* in the section.





The bar P Q is an iron lever, which in the above diagram is of the second kind, having at P a pin, *mn*, like that of a balance, turning in two steel rings on a pillar of stone sunk in the ground, or of iron resting on the bottom of the box; a steel pin, *pq*, formed also like that of a balance, with its edge upwards, passes through the bar P Q; and upon this rest the edges of the prisms at *cd* and *c′d′*, as shown in the section.

The platform supporting the carriage which is to be weighed, and which is represented at M N in the section, has below it four iron feet, of which two appear at X and Y; and the under surfaces of these feet are formed with hemispherical cavities which rest on the points of four conical steel pins at *t*, *u*, *t′*, *u′*, on the two lever-frames; consequently the weight on the platform pressing at these four points, the prisms at *cd*, *c′d′*, are forced down upon the pin *pq*; and this last then presses down the extremity Q of the lever P Q. This lever itself may be made to act as a steelyard; or, by a rod or chain, the extremity Q may be connected with one arm of a balance or steelyard above the machine; in either case the weight of the carriage may be ascertained.

It is evident, from the nature of the lever, the pressure of the platform itself being balanced by a constant weight at Q, that if W represent the weight of the carriage, $W.\frac{at}{ac}.\frac{Px}{PQ}$ will express the pressure at Q, or the weight by which that of the carriage is determined; and this is independent of the power obtained by a steelyard which may be connected with Q. If $\frac{at}{ac}=\frac{1}{14}$ and $\frac{Px}{PQ}=\frac{1}{16}$, a weight equal to 10 pounds at Q′ will balance a weight equal to 1 ton upon the platform.

The *Spring Balance* is a machine in which the elasticity of a spring of tempered steel is employed as a means of measuring weight or force. The name is most commonly applied to machines for the former purpose; those employed to ascertain the muscular strength of men and animals, the amount of power required to move a carriage or a boat, or any other force applied in the form of a pull, being called dynamometers. [DYNAMOMETER.]

One of the simplest kinds of spring-balance is that which, when employed as a weighing-machine, is known as the spring or pocket steelyard. It consists of a helical spring formed by bending a steel wire spirally round a cylindrical mandril or axis, so as to form an extensive series of convolutions. This spring is placed in the interior of a tube of brass or iron, closed at both ends: one end of the spring abutting against the plate which closes the lower end of the tube. A rod, having a hook or loop at its lower extremity, to hold the article to be weighed, passes through a hole in the bottom of the tube, and up the inside of the spring. At the upper end of this rod is a small plate, which slides up and down like a piston in the tube, and rests upon the upper or free end of the spring; thereby causing it to collapse when a heavy body is attached to the hook at the bottom of the sliding-rod. The machine is supported by means of a hook or ring attached to the upper end of the tube; and the extent of the motion of the spring, and consequently the weight of the body suspended from it, are indicated by the degree to which the rod is drawn out of the tube. For this purpose a graduated scale is engraved upon the rod; the divisions indicating the extent of compression produced in the spring by the application of known weights. Several spring-balances on the same principle are made for various purposes. That known as Salter's balance has a brass plate attached to the tube or cylinder, within which the spring is enclosed, and a vertical slit through the plate and tube. A scale is engraved on the face of the brass plate, and the weight is indicated by a pointer which moves up and down with the spring, with which it is connected through the vertical slit in the tube. Martin's "index weighing-machine" acts upon the same principle, but has a circular dial-plate and a revolving pointer or index, resembling the hand of a clock. On the axis of the index, but at the back of the dial-plate, is a toothed pinion, which is turned by a straight rack attached to the vertical rod, which rises and falls with the spring. The index remains in a vertical position when the balance is unloaded, and deviates more or less from it when a weight is attached to the hook. One advantage of this construction is that the point of the index traverses a much greater space than the spring itself, so that a small movement of the spring becomes readily discernible.

Spring-balances with helical springs are applied to several useful purposes besides that of ascertaining the weight of bodies. A spring of this character is sometimes used to hold down the lever of the safety-valve in a steam-engine boiler, the movement of the index also showing the pressure of the steam. Such an apparatus is useful in a locomotive engine, the shaking motion of which might derange a valve loaded with moveable weights. A helical spring-balance forms also a good cable-stopper. When applied to the measurement of muscular force, the tractive power of a locomotive carriage, &c., one end of the cylinder in which the spring is enclosed is made fast to an immoveable object, and the power to be measured is applied to the sliding-rod. If used to ascertain the force necessary to draw a carriage, the spring is placed between the carriage to be drawn and the power employed to draw it. In using a spring-dynamometer for this purpose, especially when the carriage is moved by animal power, some inconvenience is occasioned by the vibration of the index with every trifling variation in the force applied, to remedy which Mr. H. R. Palmer contrived an apparatus in which the quick vibration of the spring is checked by means of a piston moving in a cylinder filled with oil. A very narrow space is allowed for the oil to pass between the edge of the piston and the cylinder, so that a considerable resistance is opposed to the motion of the piston and the springs, and the index consequently represents the mean amount of force applied without being affected by sudden variations.

The ingenious method adopted by Mr. Martin for transmitting the motion of a spring to an index moving upon a circular dial-plate, is applicable to spring-balances of other than the helical construction. It was used by M. Hanin, a French gentleman, who was rewarded by the Society of Arts, in 1790, for an apparatus for showing at one view the weight of an object according to several different scales or systems of weights. His machine which is described and figured in the ninth volume of the Society's 'Transactions,' consists of a dial-plate, on which are marked several concentric circles, divided according to the systems of weights used in different countries, and an index moved by a rack and pinion, as before described. The spring, instead of being of a helical form, is semicircular; its upper extremity being firmly attached to the back of the dial-plate by means of screws, while its lower end is attached to the hook which carries the weight, and the sliding-rack by which the index is moved. Marriott's patent weighing-machine is similar to that of M. Hanin, but the spring is a perfect ellipsis, with its longer axis laid horizontally. The stem to which the ring for holding the apparatus is attached is fastened by a nut and screw to the middle of the upper side of the spring; and the rack, with the hook which holds the article to be weighed, to the corresponding point on the lower side of the spring. The spring, rack, and pinion are enclosed in a circular box at the back of the dial-plate, the periphery of which serves as a stop to prevent the spring from being overstrained. A similar apparatus, contrived by M. Regnier, has been used as a dynamometer, as well as a weighing-machine.

A scale-plate or dish may be added when necessary to any of the spring weighing-machines which have been described. On account of the absence of weights, and the great simplicity of their application, spring-balances are useful in cases where extreme accuracy is not required, especially when a portable weighing-machine is desirable. Machines for ascertaining the weight of the human body are often made on this principle, a kind of chair being suspended from the spring.

WEIGHT. There is nothing to say on the feeling of weight after what has been said in PRESSURE; nor is it possible to give any idea which will be half so good as that which presents itself in raising a heavy body from the ground. The measure of weight is weight itself [BALANCE], and two weights are equal which counterpoise each other when placed at the ends of equal arms of a self-poising lever.

The weight of a body, that is, of a given bulk of known substance, is referred to that of water by what is called the SPECIFIC GRAVITY of the substance. It is said, for example, that the specific gravity of ivory is 1826, when that of water is 1000. This means that any bulk of ivory is more weighty than the same bulk of water in the proportion of 1826 to 1000. When the specific gravity of water is called 1, that of ivory is 1·826. Since a thousand ounces avoirdupois of water are nearly a cubic foot, a more popular notion of the meaning of specific gravity may be given, in this way:—To say that the specific gravity of a substance is 1·826, that of water being 1, is to say that a cubic foot of it weighs 1·826 × 1000, or 1826 ounces nearly. More correctly, from 1000 times the specific gravity (water being 1), subtract three times that specific gravity, and add its 73rd part: the last step may be left out for common purposes. Thus, the specific gravity being 4·817, 4·817 × 1000 − 4·817 × 3 is 4802·549, the number of ounces in a cubic foot.

But it is to be remembered, when weight is to be very accurately taken, that everybody is buoyed up to a certain extent by the air; and the weight of a body in air is less than it would be in a vacuum by the weight of its own bulk of air. Now the air varies in weight [AIR] in a manner which may be ascertained nearly by the indications of the barometer. Properly speaking, it varies in a manner depending upon the superincumbent pressure, the temperature, and the quantity of moisture contained in it. A hundred cubic inches of dry air, when the barometer is at 30 inches and Fahrenheit's thermometer at 60°, weigh 31·012 grains. In measuring standards of weight, therefore, close attention must be paid to the state of the air at the time of weighing and to the substance weighed. If an iron weight balance a wooden one in a given state of the atmosphere, for that very reason there cannot be strict equilibrium in any other state of the atmosphere; wood being at least seven times as bulky as iron, the effect produced on the weight of the wood by the alteration of the state of the air is at least seven times as much as that produced on the iron.

WEIGHT OF THE AIR. [AIR.]

WEIGHT OF THE EARTH. [EARTH, MEAN DENSITY OF THE.]

WEIGHT OF OBSERVATIONS. This article is only for the reference of the mathematical student; in MEAN will be found as much of it as an arithmetician can use by rule.

This term was first applied in the manner stated in the article MEAN. An observer decided the relative merit of his observations by his unassisted recollection of the impression made by them upon his mind at the time, and affixed *weights* to them; that is, supposing A_1, A_2, &c., to be the n results of observation, he attached numbers c_1, c_2, &c., proportional to their presumed goodness, and used $\Sigma cA \div \Sigma c$ instead of $\Sigma A \div n$, for the average. Instead of c_1, c_2, &c., any numbers proportional to them may obviously be used: and in applying the higher branches of the theory of probabilities, it was found that a certain mode of obtaining c_1, c_2, &c., while it gave the above mode of using these numbers in the formation of an average, made them applicable to other important uses. We here give a sketch of the results of this method in its simplest parts.

1. When a number of discordant observations, made under circumstances in which positive and negative errors are equally likely, do not differ much from each other, and when it is exceedingly unlikely that the truth can differ much from the observations, it may be presumed that the chances of the error of any one of those observations lying between x and $x + d\,x$, and between a and b, are severally of the forms

$$\sqrt{\frac{c}{\pi}}\,\epsilon^{-cx^2}dx \quad \text{and} \quad \sqrt{\frac{c}{\pi}}\int_a^b \epsilon^{-cx^2}dx,$$

where c is a constant dependent on the goodness of the observations, and $\pi = 3{\cdot}14159\ldots$, $\epsilon = 2{\cdot}71828\ldots$, as usual. Even if this law of error do not exist, it is found that the treatment of *a considerable number of observations*, whatever * may be the law, is reducible to the same rules as those derived from this law, which is now universally assumed by those observers who apply the theory of probabilities to their results.

2. The constant c is called the *weight* of the observations, and depends upon the various circumstances which determine their goodness or badness. The greater it is the better the class of observations to which it applies. It is approximately found, for a given class of observations, as follows:—Subtract each of the observations from their mean, and let e_1, e_2, &c., be the results; then $c = n \div 2\Sigma e^2$. The sum of the squares of the departures from the average may be found by diminishing the sum of the squares of the *observations* by n times the square of the mean; and before doing this any convenient quantity may be struck off from all the observations, provided it be also struck off from the mean.

3. The *probable error* is that within which, taken positively and negatively, there is an even chance an observation shall lie. Thus if there be an even chance (A being the true result) for the result of an observation lying between $A - a$ and $A + a$, then a is the probable error of an observation. To find the probable error, divide ·476936 by the square root of the weight.

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* That is, provided the law be such as common sense can admit, as representing what actually takes place in human observations. It would not apply, for example, to a case in which the larger the error the more likely was it to happen.

4. The weight of the average of observations is the sum of the weights of the component observations. If n observations, A_1, A_2, &c., be made, all of the same weight c, the average is $\Sigma A \div n$, the weight of the average is nc, and its probable error is $\cdot476936 \div \sqrt{(nc)}$. But if the weights be different, say c_1, c_2, &c., then $\Sigma cA \div \Sigma c$ is the average, Σc is its weight, and $\cdot476936 \div \sqrt{(\Sigma c)}$ its probable error. In the former case the probable error of the average may be directly found from the sum of the squares of the reputed errors,* by the formula

$$\cdot67449 \sqrt{(\Sigma e^2)} \div n.$$

5. *Cæteris paribus*, the probable error of an average will not be inversely as the number of observations, but as the square root of that number. If p be the probable error of an observation, and P that of the average of n such observations, then $p = \sqrt{n} . P$. An observer who takes such a mode as gives the probable error of an observation *twice* as great as it need be, must not hope to indemnify himself for his carelessness by making *twice* as many observations as would otherwise be necessary, but must make *four times* as many.

6. If p be the probable error of an observation, an average, or other result, the following table will be sufficient to connect the probable error with other errors, for any rough purpose of estimation :—

Odds.	Against.	For.	Odds.	Against.	For.
1½	·79	1·25	7½	·22	2·32
2	·64	1·43	8	·21	2·36
2½	·54	1·58	8½	·20	2·40
3	·47	1·71	9	·19	2·44
3½	·42	1·81	9½	·18	2·47
4	·38	1·90	10	·17	2·50
4½	·34	1·98	20	·09	2·94
5	·31	2·05	30	·06	3·17
5½	·29	2·11	40	·05	3·34
6	·27	2·17	50	·04	3·50
6½	·25	2·22	100	·02	3·90
7	·23	2·27	1000	·002	4·90

This table is to be interpreted as follows :—If p be the probable error above mentioned, it is 1½ to 1, or 3 to 2, against the error turning out less than $\cdot79 \times p$, and it is 1½ to 1 for the error turning out less than $1\cdot25 \times p$. It is 8 to 1 against the error being less than $\cdot21 \times p$, and 8 to 1 for its being less than $2\cdot36 \times p$. It is 1000 to 1 against the error being less than $\cdot002 \times p$, and 1000 to 1 for the error being less than $4\cdot90 \times p$.

WEIGHTS AND MEASURES. The subject of weights and measures is one the actual state of which is prosperous in the inverse ratio of the number of books or the length of articles which are written upon it. There is nothing in it which might not, if the most natural and simple system were adopted, be described in a very few pages. We are speaking of course only with reference to a possible time; for, let that time arrive when it may, the history of the past must be a confused and repulsive subject.

In the article WEIGHT, &c., STANDARD OF, we shall give some idea of the recent history of the attempts which have been made in England to secure a permanent measure of length. These have only succeeded, at least until very recently, somewhat farther than to the extent of making it possible to restore to the merchant a system sufficiently near to that which now exists, if the latter should be lost; but they have all confessedly failed in perpetuating sufficient exactness for scientific purposes. The same may be said of the French endeavour to create a recoverable standard by the measurement of the earth. [TRIGONOMETRICAL SURVEY.] So that in fact we are now come back again to the old notion, that the true way to maintain a measure is to construct accurate copies out of durable material, and to preserve those copies with care.

The measures of time (of which we speak more particularly in YEAR, TIME, PERIODS OF REVOLUTION) are the only usual ones in which a natural standard exists; to which we may add, that in the kindred operation of counting there is something of the same kind. The phenomena of the daily revolution of the earth, and the ten fingers on the two hands, have secured to the whole human race, above the degree of the lowest savages, one mode of assigning periods of duration and large collections of number. But even in these two subjects details have differed considerably in different times and countries; and much more has this happened with respect to measures in which the choice of a standard is purely arbitrary, as in the case of length, surface, capacity, and weight. The angle is another magnitude which has a natural measure [ANGLE]; and, as this has never been out of the hands of geometers, a greater uniformity has prevailed in the measurement of angular magnitude than of any other whatsoever. The measures of length obviously regulate those of surface and capacity. There is no other way of defining an area or a solidity, except by describing, for the area, lengths, and for the solidity, surfaces, by which the area or solid may be bounded in a given manner. Measures of weight may be obtained by defining, as standards, given bulks of given substances; and as water is the most common and most easily purified of all substances, it has been chosen by common consent as the referee for such standards. A measure of length then is all that is wanted in the first instance; and most nations, ancient and modern, have been in the habit of referring all the resulting measures to those of length alone. Nevertheless, there is no small difficulty in obtaining a comparison of a measure of weight deduced from length with one already existing, in such a manner as to perpetuate the latter, if the utmost accuracy be required. (Kater, 'Construction and Adjustment,' &c., 'Phil. Trans. 1826.) So that the commissioners who last reported on the subject advise that the standard of weight shall no longer be deduced from that of length, but shall be simply a piece of metal or other durable substance.

It is not our object in this article to consider weights and measures in a scientific point of view, but simply to give some historical account of the measures actually in use, and some tables of the principal ones, ancient and modern. There is no subject whose history is more distinctly divided into three periods, ancient, middle, and modern, than that of weights and measures. The ancient period, ending with the decline of the Roman empire, during which the classical standards were preserved and employed; the middle period, during which, while the names and relations of the classical measures were preserved among the learned, the standards were lost, and the various differences of national measures began to exist among the people; the modern period, which hardly begins before the 17th century, in which the discrepancies of national measures were noted, and the attempts at a system founded upon natural philosophy began to be made.

The origin of measures of length is unquestionably to be found in the parts of the human body; both their usual lengths, roughly speaking, and their names, establish this beyond a doubt. The foot, the digit, the palm, the span, the cubit, &c., are in all languages derived from the same source; nor, in the popular view of measurement, do they materially differ in length: the *yard* is but a variety of the word *rod*, and has no intrinsic meaning. It is also unquestionable that in former times, when authentic measures were not so easily *to be* obtained, the hands, arms, and feet were much more frequently used than they are at present, when every workman, however humble, is in possession of a measure. George Agricola, presently named, says *that* in his time (the beginning of the 16th century) the French workmen commonly measured a foot by joining the extremities of the thumbs, clenching the fingers, and keeping the thumbs as widely *extended as* they could: "vulgo pedem metiuntur opifices manibus in pugnos contractis et porrectis pollicibus altrinsecusque obversis:" nor is this a bad measure of a French foot. At what period the slightly variable measures derived from the living man were first exchanged for a fixed and legal average or other conventional value, whether among the Greeks or Romans, is unknown. All that can be said is, that *none of* the earlier writers enter otherwise than incidentally upon the question, and that the fixed and legal measures were of early date. Most authors give some little information upon the subject; even the poets are frequently cited for their allusions. Fixing the end of the ancient period about the middle of the 6th century (simply because the chain of writers who are cited on ancient weights and measures ends *there*), and omitting names as well known as Homer or Virgil, Hesychius or Suidas, Pliny or Vitruvius, there is direct information on the subject in the works or fragments of Cato, Celsus, Columella, Dioscorides, Galen, Hero, Julius Frontinus, Julius Pollux, Martianus Capella, Modestinus, Oribasius, Palladius, Paulus, Pomponius, Priscian (who wrote expressly on the subject), Proclus, Rhemnius Fannius (*who* wrote a poem on the subject, often attributed to Priscian), Scribonius, Boetius, Festus Pompeius, Ulpianus, Volusius Mæcianus, and Varro.

It may be convenient to end the middle period and commence *the* modern with the work of Lucas Pætus (1573), as being the earliest of the writers who are frequently cited for success in their attempts to restore the almost forgotten values of the Roman measures. But *this* middle period may be divided into that which preceded and followed the invention of printing. All that took place in the former part of it is a blank; we know but the result, namely, the (probably *gradual*) introduction of measures differing from those of Rome in magnitude, though retaining the same names. Nevertheless the writers, as we have seen in MILE, retained, besides a uniformity of expression, an intended uniformity of meaning: if they had not the Roman foot and mile, they thought they had. When the German mile was introduced, which was about four Roman miles, the latter were called Italian miles. An abundance of passages might be cited from writers of different countries about the beginning of the 16th century, when books began to be plentiful, all coinciding in requiring the following explanation, namely, that the learned had among themselves, or believed they had, a system of measures in terms of which they communicated with each other, not recognising nor in any way alluding to the common or vernacular measures. It is our supposition that this system began in ignorance that the national measures really did differ from one another at all, and was continued under the impression that a common system was desirable, attainable, and, by keeping to the Roman measures, attained.

As this point in the history of measures is not alluded to by any metrologist, and as some of its consequences are remarkable, it will be desirable to state some proofs of our assertion. So far as we can find, it was hardly thought necessary, even after the 16th century had commenced, and certainly not before, to mention the scale of measures;

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* The departures from the average above mentioned: the average being taken for the truth, these departures are taken for the errors.

the Roman system was taken for granted. Roger Bacon, when speaking of a foot or a mile, compares statements of Ptolemy, Pliny, and writers of his own time, without a word of suspicion that there could be any difference between the several measures; though his own statements from modern travellers [MILE] prove that they had a mile very different in length from that of the Romans. In the Geography* of Laurentinus Corvinus (Basel, 1496), all that he says on measures is in six words, explaining the single addition which had been made to the Roman system: "Italorum quatuor unicum miliare nostrum mensurant." Lebrixa or Antonius Nebrissensis ('Cosmographiæ Introductio,' Paris, 1533), lays it down that his own foot and his own pace are those of the Romans, he being a man of moderate stature; and having once arrived at a conclusion respecting the Roman pace, he takes it for granted he has the proper foot of his own time: he adds that he has made some verifications on itinerary distances. This idea of the actual use of the human members was a very common one: George Agricola, whose work, 'De Ponderibus et Mensuris,' was much in use, and several times reprinted (Paris, 1533; Venice, 1535; Basel, 1550, and perhaps oftener), would almost seem to hint, in addition to what we have already cited, that the actual measures of his day, as used among merchants, were taken from the body: the measures of length, he says, are "membra humani corporis, perticæ, arundines, funiculi." This can hardly mean that measures, such as the foot, the cubit, &c., were only *originally derived* from the human body; for such an explanation would require us to say that the *arundo* and the *funiculus* were names of measures, which was certainly† not the case. The word pertica is ambiguous; it is both a pole and the measure derived from that pole: had it not been from the double meaning of that word, we should have been quite positive of what we now think by far most probable, namely, that Agricola means to say that people in his time measured by the parts of the body, poles, reeds or canes, and strings. This work of Agricola, though intended to be on the weights and measures of his own time, is in reality wholly occupied by discussions on the Greek and Roman measures. He is the first, he says, who in modern times recovered the distinction between the Greek and Roman measures, which had been entirely lost, or at least never mentioned, by his immediate predecessors. It was not uncommon to illustrate the table of measures by drawings of the human body, with descriptions of the foot, palm, &c., as in the 'Cosmographia' of Peter Apian, reprinted several times in the first half of the 16th century. No other reference to a standard of length is given; and the table and drawings are made in such a manner, that nothing but our habit of using other modes of measurement would make any one doubt for a moment that actual reference to the human body is intended. The complete table of the 16th century is as follows:—the breadth (not the length, as is particularly stated) of four barleycorns makes a digit, or finger-breadth; four digits make a palm (measured across the middle joints of the fingers); four palms are one foot; a foot and a half is a cubit; ten palms, or two feet and a half, are a step (gressus); two steps, or five feet, are a pace (passus); ten feet are a perch; a hundred and twenty-five paces are an Italic stadium; eight stadia, or a thousand paces, are an Italic mile; four Italic miles are a German mile; and five Italic miles are a Swiss mile. It will appear most probable from the preceding statement, that the foot was considerably less even than the ancient Roman foot of 11·6 English inches. The average human foot certainly has not that length; the average foot of an adult Englishman is 10·26 inches. The table just mentioned, derived, as we shall see, from the Romans in most of its parts, is founded upon a notion which is very near the truth in a well-proportioned man, namely, that the breadth of the palm is the 24th part of the height; the length of the foot, the sixth; and the length of the cubit, or from the elbow to the ends of the extended fingers, the fourth.

It was the practice of the 16th century, in which books were written for all Europe, and not for that part of it alone in which the writer lived, to set down on the page printed lines representing the length of a foot, or palm, according to what the page would admit. The term frequently used was "figuratio:" thus a long line extending down the page, marked "figuratio pedis," means that the length of this line at the time it was printed is that of which the author speaks. No instance was ever‡ produced in which such a line was merely a representation, put down for the purpose of showing subdivisions, or in which it was treated by any succeeding writer as other than an absolute facsimile.

The figured foot, or paper-foot as we may call it, requires to be lengthened, as an allowance for the shrinking of the paper. The surest case in which we can accurately ascertain in what proportion this shrinking has taken place, is in the plate of Dr. Bernard's work on English weights and measures, in which a line which is described as 7 English inches has shrunk to 6 inches and $\frac{25}{30}$ths, or in the proportion of 42 to 41. Other instances give smaller* amounts of shrinking: in two different copies of one work we find the difference between two impressions of the same foot agreeing within $\frac{1}{100}$th of an inch in about ten inches. It is very unlikely that, if the shrinking had been perceptible, two copies should have shrunk so equally. We adopt this ratio of 42 to 41, and the more readily, because the larger allowance we make the more is our final conclusion weakened: this final conclusion being, that the geometers of the 16th century used a much shorter foot than the Roman.

That the mathematicians just named did use a set of measures among themselves, in order to avoid the diversities of popular measures, is established by the express assertion of Clavius, who died in 1612, aged 75, and is therefore a contemporary authority. He says, in his commentary on Sacrobosco, "Enumerandæ sunt mensuræ quibus mathematici, maximè geometræ, utuntur. Mathematici enim, ne confusio oriretur ob diversitatem mensurarum in variis regionibus (quælibet namque regio proprias habet propemodum mensuras) utiliter excogitârunt quasdam mensuras, quæ certæ ac ratæ apud omnes nationes haberentur." He then gives the same table as that above. On looking at some of the earlier writers of the 16th century, we find a foot which is figured as ten English inches in length, after the shrinking of the paper is allowed for. First, Fernel,† who measured a degree of the earth, speaks of the foot which he used in two distinct works, the 'Monalosphærium' (Paris, 1526) and the 'Cosmotheoria' (Paris, 1528), in which last the degree is described. In the first work he gives his foot, or "figuratio pedis geometrici," which he says is to be chosen with great care, on account of the great diversity of measures. This paper-foot is now within a sixtieth of an inch of nine inches and two-thirds (English), which, increased in the proportion of 41 to 42, is nine inches and nine-tenths. In the second work, he says, that five of his own paces, or those of ordinary men, make six geometrical paces. Now the pace of an ordinary man, or two steps, is almost exactly five English feet, which is the double of the regulation step of the army in England. Paucton (p. 187), from actual experiment, gives what amounts to 59 inches and 7-tenths English. At sixty inches per pace, Fernel's foot is then ten inches (English) exactly; at 59·7 inches it is 9·95 inches. The two descriptions agree so well, that Fernel's foot may be considered as very well determined; nevertheless, Picard, Cassini, Montucla, Lalande, and Delambre have all taken it for granted that by a foot Fernel could have meant nothing but the Parisian foot (12·8 English inches), and have therefore considered him as having (by accident, they suppose), measured his degree with very great correctness, whereas, in fact, he is fifteen miles wrong. Budæus (followed by Glareanus and others) had, a few years before (1515), in his treatise, 'De Asse,' the earliest work on Roman measures, &c., declared that the Roman foot was the same as the Parisian; and Picard, &c. seem to have taken it for granted that Fernel followed Budæus. They might have learnt from Lucas Pætus that this foot of Budæus was "reprobated by all as having nothing in common with the Roman foot." The treatise of Stöffler, 'Elucidatio Fabricæ Ususque Astrolabii' (Oppenheim, 1524), contains his configuration of the digit, palm, and foot, separately, the foot being also divided into palms. These agree exceedingly well with one another, and the foot on the paper is precisely nine inches and three-quarters (English). This increased in the ratio of 41 to 42, gives 9·98 inches. The author speaks of the digit, &c. as being the celebrated measures which are used by all or most, and gives no hint whatever of his having made a measure for himself. It may here be noted that the English writers of the period make little mention of this book-system, and, when they do mention it, sometimes confound it with the common and popular system. Thus Blundevil, in his 'Exercises,' tells us that the *German foot*, according to Stöffler, is two inches and a half less than ours; alluding, no doubt, to the foot we have just cited.

Since the 'Penny Cyclopædia' appeared, we have examined several other figured feet; for some of which see De Morgan, 'Arithmetical Books,' pp. 8, 9. The results accord very well with those given above; and the mean of the whole gives a foot of 9·85 inches. But Fernel and Stöffler are the best authorities, because they are the best names, have given the whole foot, and have taken the greatest pains with the subdivisions. The mean of their results, before allowance for shrinking, is 9·7 inches: that of the barley, presently mentioned, is 9·8 inches. The allowance for shrinking is, as above given, perhaps too great; and 9·8 inches is, it may be, as good an estimate as can be given of this once well-known measure.

There is little reliance to be placed on the barley standard; nevertheless, this addition to the Roman system of measures must have been made by some who had tried it: we can hardly suppose that writers would in all cases carefully state that four grains of barley placed side by side give their first and lowest measure, unless they were at least repeating a well-established tradition, founded upon an actual mode of measurement. According to this mode, 64 grains, placed side by side, ought to give their foot: we believe it will be found very difficult to make any barley of our day give more than 10 inches. On trying the first grains we obtained, we found that, by picking out the largest grains, 33 of them just gave more, and 32 less, than five inches: but that, taking the grains as they came, 38 gave only five inches. Not wishing however to trust to one trial, we procured the largest specimens of barley which could be got from two different and distant parts of England, and from these specimens, already selected as choice samples, we picked out the largest grains. In a first sample, 33 grains placed side by side gave five inches; in a second, 33 grains gave five inches and one-tenth; in a third, 33 grains gave also 5 inches and one-tenth. And yet these samples differed apparently in bulk; but on examination we found that the *lengths* of the grains differed materially, their breadths very little. So that the ancient English standard which depended, or was said to have depended, upon the lengths of barley-corns placed end to end, was not founded upon so sure a method as that above described, which depended upon the breadths. The foot of 64 barley-corns derived from the average of the preceding (rejecting that from the smaller grains of the London sample) is 9 inches and eight-tenths of an inch, rather smaller than might be supposed from the other methods of judging, which, however, it must be remembered, have been pushed to their utmost.

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* Remarkable as being probably the last work in which America is not mentioned.

† We do not forget the *canna*, but this was only an isolated Italian measure, not likely to be named as a technical term by Agricola, writing in France, and putting all measures under four heads.

‡ We have found *one*, in the work of Neander (1555), in which the ratios of the measures are represented by arbitrary lines. But as if to show what was intended, the words next following the figured measures are "Hactenus persecuti sumus *nomina* mensurarum," &c.

* We have taken the one which is most against us: in the 'Pathway to Knowledge,' (1596; not the work of Recorde under that name, but a translation from the Dutch, of which we can find no mention in bibliographers) a line of six English inches, figured in the translator's preface, has shrunk only by one part out of sixty. With reference to our frequent subsequent citations from this 'Pathway,' we may observe that Jeake, whose ample and laborious accounts of weights and measures (in his '*Λογιστικηλογία*, or Arithmetick, Surveighed and Reviewed,' London, 1696, but finished in 1674) makes him a very respectable witness, considers it as a first-rate authority.

† See a discussion on this case in various numbers of the 'Philosophical Magazine' for 1841 and 1842.

We feel persuaded from all that precedes, not only that at the beginning of the 16th century there was no distinction made between the measures of the learned and the Roman measures, but that the Roman foot, the foundation of all, was taken to be considerably shorter than the truth, having been probably recovered from the human body. Long after the introduction of sounder notions, we see traces of the same sort of thing. For instance, in the second edition of the mathematical Lexicon of Vitalis (1690), the first edition (1668) being silent on the matter, an article on measures is introduced in which the only authorities alluded to are the 'Dies Geniales' of Alexander ab Alexandro, in which there is nothing but description of ancient measures, and the work of George Agricola already cited. The Roman foot was recovered with tolerable ease as soon as it was looked for. Leonard di Portis, an Italian lawyer, gave its length from the Colotian foot hereafter noticed; and Lucas Pætus, another lawyer, wrote elaborately on the ancient weights and measures in 1573. Those who would see more of this subject in the 16th century must search for the writings of Alciatus, Alcasar, Geo. Agricola, Budæus, Budelius, Capellus, Montanus, Mariana, Lebrixa (Nebrissensis), Neander, Pasi, Pætus, Portius, Villalpandus, &c.

As soon as the middle period is past, the history of weights and measures down to our own time ceases to be European, and, with the exception of those of England and France, we need not, in so short a sketch as the present, give any very close account of the various national measures.

In England, it seems as if the standards were tolerably well settled and widely diffused at so early a period that the writers of this country took comparatively little notice of the system which the continental mathematicians used for their own communications. That the ear of barley and of wheat were actually used in determining the standards, seems * to admit of no doubt. The statute 51 Henry III. (A.D. 1266) enacts, "that an English penny,† called the sterling, round, without clipping, should weigh 32 grains of wheat, well dried and gathered out of the middle of the ear; and twenty pence to make an ounce, twelve ounces a pound, eight pounds a gallon of wine, and eight gallons of wine a bushel of London, which is the eighth part of a quarter." Again, 17 Edward II. (A.D. 1324) provides that three barley-corns, round and dry, make an inch, 12 inches a foot, &c. And the interpretation of the older scientific writers on measures is agreeable to the common meaning of the words. "Look to the first grounde," says Oughtred, "and principle of our English measuring, from Barley-cornes." But it is so difficult to know how much of the sharp end of a barley-corn must be cut or worn away before it becomes what was called "round," that this mode of measuring by the *lengths* of barley-corns is very indefinite. Standards were made at early periods and enforced by various statutes; one of the earliest is one of Edward I. of uncertain date, which directs that a standard of bushels, gallons, and ells, shall be kept in every town, agreeing with the king's measure. With regard to the measure of length, this country has been fortunate, and its standards have, for commercial purposes, fully deserved the name. But the measure of capacity [GALLON] remained various in spite of all acts of Parliament. In the year 1650 there were three distinct modes of determining a wine gallon: 1, From general opinion, which gave 231 cubic inches, and with which, in fact, the gallons in common use agreed, as was proved by the measurements of Oughtred, Gunter, Briggs, and others. 2, The customary standard at the Guildhall, which, though not a legal standard, was considered as such, even by the law-officers of the crown, and which, though in reality only 224 cubic inches, was always taken to be 231 inches. 3, The real legal standard, preserved at the Treasury, containing 282 cubic inches. Oughtred says that the difference between the ale and wine gallons is, "that because of the frothing of the ale or beer, the quantity becomes lesse, and therefore such liquors as did not so yield froth, as wine, &c. and the like, should in reason have a lesser measure." The Report of one of the Committees states that the wine gallon had been gradually shrinking in capacity, until it was arrested at 231 cubic inches by a fiscal * definition. That this value was laid down by the statute of 5 Anne, cap. 27, is certain; and the origin of this definition (which is inserted into a statute having nothing to do with weights and measures) seems to have been as follows:—A little after 1700, an information was tried in the Exchequer against one Barker, for having imported more of Alicant wine than he had paid duty for. On the part of the crown it was contended that the sealed gallon at Guildhall (said to contain 231 cubic inches) was the standard. But the defendants appealed to the law which required that a standard gallon should be kept at the Treasury, proved that there was such a gallon at the Treasury containing 282 cubic inches, and established, by the evidence of the oldest persons in the trade, that the butts and hogsheads which came from Spain had always contained the proper number of the real standard gallons. A juror was withdrawn, and the law-officers of the crown took no further proceedings except procuring the above act. A better instance of confusion could hardly be imagined: the legal gallon had gradually been diminished more than 50 cubic inches; the merchants in one particular trade continued to import and to pay duty by the real gallon, and were finally called to account by the attorney-general, who, in common with the rest of the world, had forgotten what the real gallon was, and sued for penalties upon appeal to what was no more a legal standard than the measure in a private shop.

There is something curious about the history of the experiment [GALLON] mentioned by Ward, who was an eye-witness, and wrote just after the statute of Anne, when his account could do no harm. The gallon was found to be 224 (Wollaston afterwards found it to be 224·4) cubic inches, that is, the sealed gallon at Guildhall: but, "for several reasons, it was at that time thought convenient to continue the former supposed content of 231 cubic inches." This means, as explained by the Committee of 1758, that the Lords of the Treasury direct an authority to be drawn for gauging according to the Guildhall gallon: the merchants immediately petition to be allowed to sell as they were gauged; the commissioners of customs do not follow the order (which however it does not appear was ever signed); and when the Lords of the Treasury take the attorney-general's opinion upon it, they are recommended to make no change: "For if the usage of gauging is departed from, he knows not where we shall be, because resort *cannot* be had to the Exchequer for a standard to which almost all the statutes refer; *for* there is none there but what the king will be vastly a loser by."

The old division of the gallon into that of wine measure, ale and beer measure, and dry † measure, was not only unknown to the law, but even to the writers on arithmetic, till the beginning of the 17th century. Nor when Briggs, Oughtred, &c. measured the gallons, did they divide them into more than two kinds—for ale and wine. Oughtred, who measured pecks, bushels, &c., and thence found 272¼ cubic inches for the deduced gallon, imagines this to be the ale gallon. It was undoubtedly the old Winchester gallon, before its content was a little reduced by the statute of 1697; this gallon still continued in use in Ireland up to the introduction of the imperial measures; and even in England, as late as 1727, Arbuthnot takes it for the existing dry measure. Perhaps we have the first time in which, and the first person by whom, the distinction of the corn and ale gallon was made, in the following citation from Wyberd ('Tactometria,' 1650, p. 266): —"Now as to Mr. Oughtred's ale gallon of 272¼ inches, the said Mr. Reynolds" (John Reynolds, a clerk in the Mint, often referred to by Wyberd as a mathematician and experimenter) "indeed alloweth of such a Gallon measure, but not for any liquid thing, but for drie things, as Corne, Coals, Salt, and other dry things measurable by this kind of Measure, and so calleth it the drie Gallon measure: and thereupon he wil have to be 3 severall Gallons (or other like Measures), one for *Wines* (which also serveth for oiles, strong-waters, and the like), another for *Ale* and *Beer*, and a third for *Corne*, *Coales*, and the like." Wyberd, rejecting the distinction of the dry and ale gallons, made his wine and ale gallons to be 224 and 266 cubic inches, by a series of carefully conducted experiments: it is singular that a good experimenter, with access to existing standards, and as good an experimenter to suggest something like the actual truth, should not have been able to find out the mere existence of the largest or ale gallon, and it shows the extreme confusion in which the subject was then enveloped.

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* We do not believe the story of Henry I. ordering that the yard should be of the length of his arm.

† A silver penny.

* We were wrong, we believe, in stating in GALLON that the *wine* gallon was determined by statutes of 1689 and 1697: these related to the other gallons. But there is singular confusion in the Reports of the Committee, which nothing but a new search into the actual statutes will remove.

† We do not mean that there was no distinction between liquid and dry measure, but that there was no distinction between the gallons of those measures. Thus Mellis, in the arithmetic appended to his treatise on book-keeping (1588), very distinctly separates the liquid and dry measures, but uses only one gallon, namely that of which the pint is one pound. It may be worth while to add that the mile of 1760 yards is mentioned by this writer four years before it became the *statute* mile.

The preface to the 'Pathway of Knowledge,' already cited, makes no distinction between the ale and wine gallon; it says that the wine gallon is the same as that of ale, and contains eight pounds of wine; it also makes the corn gallon contain eight pounds of wheat.

There has been in various quarters a disposition to suppose that the varieties of gallons arose from the varieties of pounds, since the original definition of the gallon depended upon the pound. This we think exceedingly likely: we do not imagine that it was done of set purpose, but only by confounding one species of pound with the other, in the way of common mistake. There is among most antiquarians a perverse unwillingness to admit human frailty among the explanations of the phenomena of former times, which has caused many an hour to be thrown away in trying to reconcile the Greek musical scales [TETRACHORD], and many more in finding out for the rude forefathers of all kinds of nations an accurate and self-consistent system of weights and measures. Though even in our day, a learned body,* legislating for educated men, after declaring in one paragraph that none but troy weight is to be used, has introduced averdupois weight in the very next paragraph,—we never permit ourselves to suppose that such a thing could have taken place in the reign of Henry VIII. or Elizabeth. Now it certainly does happen that there is a close relation not only between the old gallons and the weights, but even between the different versions of the old gallons and the weights. There was a gallon of 282 cubic inches, in the Exchequer as a standard; there was one of 272¼ inches, in common use; there was one of 231 inches, in common use; and there was one of 224 inches, in the Guildhall. Now 282 and 232 are, as near as integers will show it, in the proportion of the pound averdupois to the pound troy, and 272¼ and 224 are as nearly in the same proportion. It is unlikely that this should have been accidental.

Common usage, in the 16th century, made more distinctions of measures than have lasted. The editor of the 'Pathway of Knowledge' gives four sorts of pounds as in use: the Tower pound (already mentioned in TROY), the troy and "haberdepoys," the subtill, and the foyle. The word *subtill* was not the one mentioned in TARE, at least one would suppose so; let the reader try to understand it himself:—"The poundes subtill, so tearmed for that in in small quantitie it may bee made ratable to represent anye other greater waight whatsoever, as foure penny waight troy, or less to answere in due proportion unto the whole pound Troye, with all his parts, every parte sensible and severally to be handled. This waight is private, to assaye Maisters and such as can make triall of minerals, and not knowne to many other, neither is there any use thereof, in ordinarie accompts." This seems to mean that any small piece, such as an assayer would cut off for trial, was made to represent a pound, and the fineness expressed in ounces of that small pound would of course represent that of the actual pound. The pound foyle was less than the pound troy by its fifth part, and was used for gold foil and for wire, and for pearls. In the two former cases it obviously means that the workman paid himself for labour and loss by selling four-fifths of a pound of wire or foil at the price of a pound of bullion. And many varieties of measure arise in this way, namely, by varying, not the price of a given amount, but the amount of a given name at a given price. A wholesale bookseller now says that he sells 25 *as* 24, meaning that he who buys two dozen shall have one more; but in the 16th century, had this usage existed, it would have been put down that two dozen of books *are* twenty-five.

It is needless to give an account of the old standards of weight mentioned by the committee of 1758, as many of them are lost; a much greater agreement was found to exist between those made at various times than was observed in regard to the standards of capacity. The origin and history of the different weights is alluded to in AVERDUPOIS and TROY; of the standards of length in WEIGHTS AND MEASURES, STANDARD, in which last article will be found an account of the transition to the now established *imperial measures*. The day is probably distant when the English public shall enjoy the advantages of a uniform decimal system of weights and measures—the only one which is sure of stability. An opinion is gaining ground that the best method of ultimately attaining this end is by beginning with the coinage, and this was recommended by the commissioners who reported on the subject. [WEIGHTS AND MEASURES, STANDARD.] Nothing, as it fortunately happens, can be easier than this change: the introduction of coins of two shillings each, in place of the half-crown, might be followed by that of coins of twopence-halfpenny each, without requiring any alteration in the habits or calculations of any one. It is the advantage of this proposition that the two new coins might be learnt as parts of the old system, before the subsequent alteration of the copper is made. As soon as these coins are well established, an alteration of four per cent. in the copper coinage, or the enactment that *twelvepence-halfpenny* shall pass for the silver shilling, is the whole step requisite to complete the process; and the pound will then consist of ten *two-shilling* coins (under their proper name), the two-shilling coin of ten *twopence-halfpenny* coins (also under their proper name), and the twopence-halfpenny of ten farthings as at present. As soon as this change is made, and the convenience of its arithmetic found by experience, it will not be long before there is a demand for the extension of the principle to weights and measures. And it would be well if those who endeavour to bring about a reform in this matter would remember that change of coinage is the only change which a government can immediately command—that for one calculation which is made upon goods, hundreds are made upon money—and that, if the small alteration which is required to make the coinage* purely decimal cannot be attained, there is little chance of the more extensive changes which the weights and measures will require.

We now describe the English weights and measures as they stood on the last day of the year 1825, immediately before the introduction by law of the imperial measures, with some remarks on their states at different times. As it is not to such an article as the present that the young arithmetician will refer, it will not be necessary to give more than a condensed set of tables. For the modern continental measures which follow, we have to acknowledge great assistance from Dr. Kelly's 'Cambist,' the standard work on the subject.

Troy Weight.—This weight is said to have always been the standard weight of the country: on this assertion we have some doubts; but this is not the place to enter on them at length. The pound is 12 ounces; the ounce is 20 pennyweights; the pennyweight is 24 grains. The pound is 5760 grains. There is but one grain in use, whether troy or averdupois, and a cubic inch of pure water is 252·458 grains (barometer 30 inches, thermometer 62° Fahr.). A cubic foot of water is 75·7374 pounds troy. Wheat and bread were once measured by this weight, but latterly only gold and silver. It is usual to say that precious stones are also measured by troy weight; but, as may be supposed, the measure of these is the grain. The diamond is measured by carats of 151½ to the ounce troy; so that the carat is 3⅙ grains, very nearly. In pearls, the old foil measure already noticed still exists; for the pearl grain is one-fifth less than the troy grain. In the 17th century the goldsmiths divided the ounce troy into 24 carats of four grains each for gold and silver: so that the pound troy contained 1152 gold-carat grains. They also divided the ounce into 150 carats of four grains each, for diamonds: so the pound troy contained 7200 diamond-carat grains. But now the CARAT has only the sense noted under that word, for gold and silver; and is altered as above for diamonds.

According to the old statutes, the pound troy is 7680 grains; for 32 grains are to make a pennyweight, 20 pennyweights an ounce, 12 ounces a pound. It is not known when or why the pennyweight was first† made 24 grains. In some old books a grain is 20 mites, a mite 24 droites, a droite 20 peroites, and a peroite 24 blanks. This division of the grain into 230,400 parts must of course have been book-learning: it is said to have been confined to the *moneyers*.

In Swallow's Almanac for 1673, we find the troy weight given as for "pearls, precious stones, gold, silver, bread, and all manner of corn and grain; and this weight the apothecaries ought to use."

Apothecaries' Weight.—In *dispensing* medicines, the pound troy (Does that weight ever occur in prescriptions?) is divided into 12 ounces, the ounce into 8 drams, the dram into 3 scruples; consequently each scruple is 20 grains. But in buying and selling medicines wholesale, averdupois weight is and always has been used. The 'Pathway,' so often cited (1596), says, "all physicall drugges" were weighed by averdupois, and Jeake (1674) says that "many" (only many) of the "physical doses" are weighed by what we now call apothecaries' weight. The fact seems to be that in the first instance the more precious drugs, as musk, were weighed by troy weight, in the same manner as the more precious metals; and that the common medicines were dispensed by fractions of what was then the common pound, as we shall see under the next head.

Apothecaries' fluid measure.—In 1836, in the new edition of the 'Pharmacopœia,' the College of Physicians prescribed the use of the following measure:—60 minims make a fluid dram; 8 fluid drams a fluid ounce; 20 fluid ounces a pint. For water this is actual weight as well as measure, since the imperial pint‡ is 20 ounces averdupois of water; but for other liquids the fluid ounce§ must merely be considered as a name given to the 20th part of a pint. The minim of water is as nearly as possible the natural drop; but not of other substances, the drops of which vary with their several tenacities.

According to Dr. Young (who has reduced them from Vega), the apothecaries' grains used in different countries are as follows:—1000 English grains make 1125 Austrian, 956 Bernese, 981 French, 850 Genoese, 958 German, 978 Hanoverian, 989 Dutch, 860 Neapolitan,

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* We allude to the College of Physicians, in the matter of the fluid apothecaries' measure, presently mentioned. The mistake was exceedingly natural, almost inevitable, but it shows what extreme care is necessary.

* We leave these remarks as they stood in the 'Penny Cyclopædia,' without any allusion to recent discussions.

† Cocker, Wingate, &c., say that a pennyweight is 32 *real* grains, and 2 *artificial* grains.

‡ The old pint was more nearly a pound, and some of our readers will remember the old saying,—

> "A pint's a pound
> All the world round."

The second line of this was certainly not true, and the first only approximately. But under the imperial system the following, which is literally true, may be substituted,—

> "A pint of pure water
> Weighs a pound and a quarter."

§ It is not noted in the 'Pharmacopœia' that the fluid ounce, when it *is* an ounce, is an ounce averdupois: a preceding sentence in that work implies that medical men are never to use anything but troy weight.

824 Piedmontese, 864 Portuguese, 909 Roman, 925 Spanish, 955 Swedish, 809 Venetian.

The recent alterations in the government of the medical profession have produced proposals to alter the method of weighing medicines. A committee of the General Council of Medical Education has given a recommendation to the following effect. The pound averdupois is to have its ounce divided into drachms, scruples, and grains, as in the present troy ounce. To effect this, a new grain is invented, being ·91145 of the present grain: and the pound is to be 7680 grains, as of old. What purpose this change can answer, or, supposing a purpose, how it can bring benefit enough to counterbalance the alteration of the grain in which all doses are now remembered, and all prescriptions written, we cannot imagine.

Averdupois weight.—The pound is 16 ounces, and the ounce 16 drams: the modern pound is 7000 grains (the same as the troy grains); whence the dram is 27 grains and 11-32nds of a grain. The hundredweight is 112 pounds, and the ton 20 hundredweight. The cubic foot of water is 62·3210606 pounds averdupois. The stone * is the 8th part of the hundredweight, or 14 pounds. The ton of shipping is not a weight, but a measure, 42 cubic feet, holding 24 hundredweight of sea-water. In the oldest mentions which are made of *haberdupois* or *averdupois*, the word is not applied to weight, but to goods weighed. A charter of Edward I. speaks, "de averis ponderis, et de aliis rebus subtilibus;" and no mention is made of averdupois *weight* before the time of Henry VIII. Wingate (quoting Gerard Malynes, whose 'Lex Mercatoria' was published in 1636) says that it serves to weigh "all kind of grocery ware, as also butter, cheese, flesh, tallow, wax, and every other thing which beareth the name of *garbel*, and whereof issueth a refuse or waste." To which the almanac of 1673, already quoted, adds, "and therefore 112 lbs. averd. is called a hundredweight."

The old merchants' pound, which was 15 ounces [TROY], may have been the origin of the modern averdupois pound. Fleta says everything was weighed by it except gold, silver, and drugs; but it is to be remembered that this does not mean that gold and silver were weighed by troy weight; for it is well known that, until a change was made by Henry VIII. in 1527, gold and silver were weighed by the Tower pound of 11¼ ounces. The modern averdupois pound is 14 ounces, 12 pennyweights, all but 8 grains troy. The standards of Elizabeth agree tolerably well with this; but it is to be noticed that, unless we suppose two averdupois pounds, one ancient and one modern, there is much reason to doubt whether the averdupois pound was uniform. Dr. Kelly says, "The old commercial weight of England, which is still retained in Scotland, is about one-twelfth heavier than averdupois, the pound being 7600 grains troy . . . . this has been long the weight in England by which the assize † of bread is fixed." Our suspicion is this, that the old commercial pound, probably differing in different places, though supposed to be uniform, gradually gained the name of averdupois; and that the standards deposited in the Exchequer in the time of Elizabeth, which certainly do not agree with the arithmetical writers of the same date, were probably derived either from this old merchants' pound of 15 ounces troy, or from a selection out of the varying specimens of a pound derived from it. In the 'Pathway' the "pound haberdupois is parted into 16 ounces, every ounce 8 dragmes, every dragme 3 scruples, every scruple 20 grains;" giving 7680 grains to the pound. This is the probable origin of the old pound which Dr. Kelly mentions, and it happens to contain precisely the same number of grains as the old statute ‡ pound before 32 grains took the place of 24 in the pennyweight. And this shows the origin of apothecaries' weight: medicines were dispensed by this old subdivision of the pound, and continued to be so after the pound of Elizabeth's standard had supplanted the old one. It was then natural that this ounce, drachm, and scruple, which were no aliquot parts of the new averdupois pound, but which were aliquot parts of the pound troy, should be referred by arithmeticians to the latter.§ Sir Jonas Moore, who had been surveyor-general of the Ordnance, and could hardly have failed to be correctly informed, gives the same pound and subdivisions. Moore's 'Arithmetic' was first published in 1650. Jeake, as late as 1674, gives the same division and the same pound of 7680 grains; and Harris, as late as 1716, does the same in the third edition of the 'Lexicon Technicum.' Jeake gives several citations tending to show that there was no universal agreement about the pound averdupois. Dalton (the lawyer) and Malynes, he says, agree in making 56 lbs. averd. equal to 67½ lbs. troy (or $6942\frac{6}{7}$ grains to the pound averd.), but *both* afterwards put 68 for 67½ (which gives $6994\frac{2}{7}$ grains). Others, he continues, affirm the pound averdupois to be 14 ounces 12 pennyweights troy (giving 7008 grains). The older writers hardly mention averdupois weight: Recorde not at all; Mellis slightly, not subdividing the ounce. Hartwell, an editor of Recorde (1648), mentions this pound of 16 ounces and 7680 grains, divided as above, and says it is used by apothecaries. Oughtred, mentioning Ghetaldi's pound of 6912 grains, compares it only with the English troy pound, without mention of any other. And this shows that, at the beginning of the 17th century, there was a complete want of agreement as to what constituted averdupois weight, which continued in some degree till the end. Nevertheless in the middle of the century, Wyberd, who measured for himself, and his friend Reynolds (before mentioned), assert that the averdupois pound is to the troy as 17 to 14 (which gives $6994\frac{2}{7}$ grains, agreeing with Dalton and Malynes), though they say that the then common notion was that the ratio was 73 to 60 (which gives 7008 grains). Moore (1679) gives as much as 7680 grains. Ward says that, by a very [illegible] experiment, he found 6999⅛ grains. Arbuthnot, apparently meaning to cite Greaves, but we cannot find the place, gives the ratio 17[illegible] : 144, or 6890⅝ grains. Down to the statute of Geo. IV., the averdupois pound varied a little, according to the notion of the writer: Dilworth makes it 6999⅛ grains; Dr. Robert Smith, 7000 grains; Bonnycastle, $6999\frac{22}{23}$ grains. And even since that act came into operation, which declares "that seven thousand such grains shall be, and they are hereby declared to be, a pound avoirdupois," an editor of the last-named writer will not obey the statute, but adds the 123rd part of a grain.

Long measure.—Three barleycorns make an inch, 12 inches a foot, 3 feet a yard, 5½ yards a pole, perch,* or gad, 40 poles a furlong, 8 furlongs (1760 yards) a mile. Also 2¼ inches are a nail, 3 quarters of a yard a Flemish ell, 5 quarters an English ell, 6 quarters a French ell. A pace is 2 steps, or 5 feet; a fathom is 6 feet. The CHAIN is 22 yards, or 100 links: 10 chains make a furlong, and 80 chains a mile. The barleycorn is now disused, and the inch is sometimes divided into 12 lines (as in France), but oftener into tenths or eighths. On our older itinerary measures, see LEAGUE and MILE. The yard is frequently called an ell in old books; *commonly*, Recorde says. Mellis says that both the yard and the ell were divided each into 16 nails. A goad is an old name for a yard and a half. The band (anciently handful), used in measuring the height of horses, is fixed at 4 inches by 27 Henry VIII., cap. 6. The furlong is probably a corruption of forty-long, from its forty poles: the old derivation, furrowlong, as long as a furrow, seems to us to carry absurdity on the face of it. The etymologists of measures are not always fortunate; Verstegan derives Troy weight from Troynovant,† the mythological name for London; and Jeake will have averdupois to be overdupois, because the pound is greater than in troy weight; while Moxon says the word means "Have your weight."

Square Measure.—A square perch is 30¼ square yards; 40 square perches are a rood (formerly also farthendele), 4 roods are an acre. The acre is also ten square chains, or 4840 square yards. Four square perches were anciently called a day's work. The rood ‡ is the same word as rod: Mellis says four *rods* make an acre. The old terms which have come down from 'Domesday Book' at latest, the hide, plowland, carucate, and oxgang, are wholly unsettled as to what magnitudes they meant.

The cubic measures, or measures of capacity, do not immediately depend upon the cubic foot, except in the case of timber. Forty cubic feet of rough timber, or fifty feet of hewn timber, make a load.

The preceding measures have been untouched by the act which introduced the imperial measures. The old measures of capacity, the wine measure, ale and beer measure, and the dry measure, are now replaced by the imperial measure.

Old Dry or Corn Measure.—The gallon is 268·6 cubic inches. Two pints make a quart, 2 quarts a pottle, 2 pottles a gallon, 2 gallons a peck, 4 pecks a bushel, 2 bushels a strike, 2 strikes a comb or coomb, 2 coombs a quarter (eight bushels), 5 quarters a wey or load, and 2 weys a last. In measuring grain, the bushel is struck, that is, the part which more than fills the measure is scraped off. Most other goods were sold by heaped measure, or as much as could be laid on the top of the measure was added. This heaped measure (which was supposed to give about a third more than the other) was at first allowed in the imperial system, but has since been abolished. Coals, which must now be sold by weight, were sold by the chaldron. Three bushels make a sack,§ three sacks a vat, and four vats a chaldron.

There was anciently a *dell*, or half-bushel (also called a *torit*), which makes the binary character of this measure almost complete. In the 'Pathway' we do not find the load or wey,‖ and the coomb is lso called a *cornook* (by Jonas Moore, *canock*), and the quarter also seam.[*] The 'Pathway,' Mellis, and Moore, &c., mention the *water easure* of five pecks to a bushel (11 Henry VII., cap. 4.), and lways in conjunction with dry measure: it means a dry measure in se at the waterside, and lime, sea-coal, and salt were measured by t. The common dry bushel was called the Winchester bushel; this ame is a remnant of the laws of King Edgar, who ordained that pecimens kept at Winchester should be legal standards.

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* There were a great many different stone weights: every one but that of 14 pounds is now illegal.

† Abolished in 1815.

‡ This circumstance and others may lead to the suspicion that the pound of which we now speak (being that which was called averdupois in the 16th century) was in reality the old standard. In 1750 Mr. Reynardson published a pamphlet, asserting that the common averdupois pound was the ancient standard, on other grounds.

§ The writers of books might invent a pound for this measure, because medicines are not dispensed by pounds, just as they might coin billions, trillions, &c. [NUMERATION], those numbers being never used. But the druggists continued to buy and sell wholesale by averdupois weight.

* In recent times the word perch has been almost confined to the square perch.

† Mr. Davies Gilbert, in his evidence before the committee on weights and measures, declared for this derivation. Lord Swinton derives it from *trois*, three; observing that the money and the money weight have three denominations each—penny, shilling, pound; and pennyweight, ounce, pound.

‡ Rod or rood merely means a piece of wood much longer than it is broad or thick. So the word rood was frequently used for the cross; and when Milton says that Satan "lay floating many a rood," he is taking the length of his hero, and not the ground which he covered.

§ In 1596 the sack was four bushels.

‖ Moore makes six quarters, and Ward ten, in a wey.

Old Wine[†] *Measure.*—The gallon contains 231 cubic inches. Four gills make a pint, 2 pints a quart, 4 quarts a gallon, 18 gallons a rundlet, 31½ gallons a barrel, 42 gallons a tierce, 63 gallons a hogshead, 2 tierces a puncheon, 2 hogsheads a pipe or butt,[‡] 2 pipes a tun. But the pipes of foreign wine depend more on the measures of their different countries than on the above. The rundlet and barrel are generally omitted, but they are both found in writers of the 16th century. Mellis gives 18½ gallons, and the 'Pathway' 18 gallons, to the rundlet. Tierce merely means the third part of a pipe, and the puncheon was anciently called the tercian (of a tun). The pottle (of two quarts) formerly existed. The anker of brandy, a foreign measure of comparatively recent introduction into England, is ten gallons.

Old Ale and Beer Measure.—One gallon contains 282 cubic inches. Two pints make a quart, 4 quarts a gallon, 9 gallons a firkin, 2 firkins a kilderkin, 2 kilderkins a barrel, 1½ barrel a hogshead, 2 hogsheads a butt, 2 butts a tun. Up to the year 1803, when the two measures were assimilated[§] by statute, this was the beer measure, and the ale measure only differed from it in that 8 gallons made a firkin. Nothing above a barrel is mentioned in the oldest tables, and the pottle (two quarts) is introduced. Two tuns were sometimes called a last.

Imperial Measure.—This measure supersedes the old corn, wine, and beer measures. The gallon contains 277·274 cubic inches, and is 10 pounds averdupois of water. Four gills are a pint, 2 pints a quart, 4 quarts a gallon, 2 gallons a peck, 4 pecks a bushel, 8 bushels a quarter, 5 quarters a load. Of these the gill and load are not named in the statute, but are derived from common usage. When heaped measure was allowed, 3 bushels made a sack, and 12 sacks a chaldron. This heaped measure was abolished[‖] by 4 & 5 Will. IV., c. 49, and the abolition was re-enacted by 5 & 6 Will. IV., c. 63, which repealed the former. These acts leave the higher measures of wine, &c., to custom, considering them apparently as merely names of casks, which in fact they are, and leaving them to be gauged in gallons. It must be remembered that in former times any usual vessel which was generally made of one size came in time to the dignity of a place among the national measures.

Wool Measure.—Seven pounds make a clove, 2 cloves a stone, 2 stones a tod, 6½ tods a wey, 2 weys a sack, 12 sacks a last. The 'Pathway' points out the etymology of the word cloves: it calls them '*claves* or *nails*." It is to be observed here that a sack is 13 tods, and a tod 28 pounds, so that the sack is 364 pounds. Jeake says this was arranged (31 Edward III., cap. 8) according to the lunar year of 13 months of 28 days each. The reason, no doubt, was, that the multitudes of whose occupation the spinning of wool formed a part might instantly be able to calculate the supply for the year or month from the amount of the day's work; a pound a day being a tod a month and a sack a year. But it would seem as if Sundays and holidays had to be made up on other days.

Tale or Reckoning.—If we were to collect every mode of counting, this would be the largest head of all. The dozen, the gross of 12 dozen, and the score, are the only denominations not immediately contained in the common system of numeration, which are universally received; and in all cases, by a dozen, a score, a hundred, a thousand, &c., were signified different numbers, composed of the arithmetical dozen, score, &c., together with the allowances usually made upon taking quantities of different goods. The "baker's dozen," for instance, which has passed into a proverb, arose from its being usual in many places to give 13 penny loaves for a shilling. The increased dozen, hundred, &c., were sometimes called the long dozen, long hundred, &c.; and this phrase is sometimes heard in our own day, when a dear price is called a "long price." The 12 dozen was formerly called the *small* gross, and 12 small gross made the great gross. The hundred was more frequently[¶] 120 than 100, the thousand generally ten hundred. Ten thousand was frequently called a last; and it is to be observed that the word last was frequently (almost usually) applied to the highest measure of one given kind. The *shock* was always 60; the dicar, or dicker, always 10, as the name imports. In measuring paper (1594), the quire was 25 sheets, the ream 20 quires, and the bale 10 reams. By 1650 the practice of reckoning 24 sheets to the quire (now universal) had been introduced as to some sorts of paper. The memory may be assisted by the phrase that a quire is the shilling of a ream, and a sheet is its halfpenny. Tale-fish, as those were called which were allowed to be sold by tale, were (22 Edw. IV., cap. 2) such as measured from the bone of the fin to the third joint of the tail 16 inches at least.

It is impossible for us to describe the various weights, measures, &c., which have found their way into use in the various counties. Dr. Young collected a list, which is printed in the second Report of the Commissioners on Weights and Measures (1820), to which we must refer for the various local barrels, bushels, hundreds, &c., and also for the awm, bag, bale, basket, bat, bay, beatment, billet, bind, bing, boll, bolt, bolting, bottle, bout, box, bucket, bunch, bundle, burden, cabot, cade, canter, caroteel, carriage, cart, cartload, case, cast, cheef, chest, clue, cord, corf, cran, cranock, cut, cyvar, cyvelin, daugh, dish, dole, drop, dupper, erw, faggot, fall, fan, flask, fodder, fotmal, frazil, garb, gaun, glean, gunny, gwaith-gwr, hank, head, heap, hide, hobed, hoop, hutch, hyle, incast, ingrain, jar, jug, keel, kemple, kenning, kibin, kishon, kiver, knot, lay, leap, lispound, llath, llathen gyvelin, llestraid, lug, maen, maise, mark, mast, math, measure, meer, meiliaid, merk, mount, mug, oxland, pack, packet, paladr, pared, peccaid, peget, piece, pig, plough land, pocket, poke, pot, pwys, quintal, reel, rees, rhaw, ridge, role, rope, roul, sack, saume, sester, sieve, skain, skin, skron, sleek, spindle, square, stacca, stack, staff, stang, stick, stimpart, stook, stored, sum, table, talshide, tankard, teal, thrave, thread, threave, timber, topston, truss, tub, tunnell, vergée, vragina, waggon-load, wain, warp, web, weight, and windle.

The old Scottish measures vary even more in the different counties than the English. The standard foot was 12·0194 English inches, 3 feet 1 inch make an ell, 6 ells a fall, 40 falls a furlong, and 8 furlongs a mile (1976½ yards). Again, 40 square falls make a rood, and 4 roods an acre. Hence the measures of length and surface are so connected that the Scottish land-chain is the 80th part of a mile, and its square the 10th part of an acre.

In Scotland, the English troy and averdupois weight obtained an early introduction, and were used with the Scottish troy weight, called also Dutch weight, and with the tron weight. The Dutch weight is as follows:—A drop is 29·722 English troy grains, 16 drops are an ounce, 16 ounces a pound (7608·95 grains), and 16 pounds a stone. This pound coincides with the old English pound already mentioned, very nearly. In the tron weight the divisions are as before; but the drop is 37·588 English troy grains, and the pound 9622·67 of the same.

The Scottish liquid gallon was 833·6272 English cubic inches. Four gills made a mutchkin, 2 mutchkins a chopin, 2 chopins a pint, and 8 pints a gallon. The Scottish pint was therefore 3 English pints very nearly. They had only one liquid measure, but they had two dry measures; the first for wheat, peas, beans, &c.; the second for barley and oats. In the first the peck contained 553·581 English cubic inches. Four lippies made a peck, 4 pecks a firlot, 4 firlots a boll, and 16 bolls a chalder. The second measure was divided in the same way, but the peck was 807·576 English cubic inches.[*]

On the Irish measures, previous to the introduction of the imperial system, there is nothing to remark, except that the coal bushel contained 10 English corn gallons, the lime bushel 8, the malt[†] gallon 272¼ cubic inches, and the liquid gallon 217·6 cubic inches. The pole was 7 yards, which made the mile equal to an English mile and three-elevenths, and the acre greater than the English acre in the proportion of 121 to 196.

We have not space to enter into the ancient history of French measures, for which the reader[‡] may consult Paucton's 'Métrologie,'

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[*] This word has been preserved as a measure of glass.

[†] For wine and spirits, cider, mead, oil, honey, vinegar.

[‡] According to Mellis, the butt was a name applied only to half-tuns of malmsey or sack.

[§] The reader would look in vain for any notice of this in books of arithmetic. Perhaps the statute was not attended to. The distinction of the ale and beer firkin is said by Ward to have existed only in London, an average firkin of 8½ gallons having been enacted for all other parts of England by the statute of Excise of 1689. But it does not follow, in matters of weight and measure, that any change was actually produced merely because there was an Act of Parliament for it.

[‖] It was abolished in Scotland two centuries ago, and re-enacted by neglect in the act of 1825. But the re-enactment did not obtain for it the slightest introduction, according to M'Culloch.

[¶] According to the old adage, the hundred was—

> "Five score of men, money, and pins,
> Six score of all other things."

And the real hundred, ten tens, was the *little* hundred; as in the old rhyme—

> "One's none,
> Two's some,
> Three's a many,
> Four's a penny,
> Five's a little hundred" [*score* understood].

[*] Our authority for the Scottish measures is 'Tables for converting the weights and measures hitherto in use in Great Britain into those of the Imperial Standards, &c., also abstracts of the jury verdicts throughout Scotland,' &c., by George Buchanan, Civil Engineer, Edinburgh, 1829. This work is as complete as a work can be: the reader may compare it with 'A proposal for the Uniformity of Weights and Measures in Scotland,' &c., second edition, Edinburgh, 1789.

[†] This was the old Winchester gallon, already mentioned.

[‡] On this work, that of Romé de L'Isle (1789) and the anonymous 'Métrologies Constitutionelles et Primitives' (1801), it may be observed that they are all vitiated by the assumption that a very accurate knowledge of the earth's diameter anciently existed, from which all weights and measures, even those anterior to Greek and Roman times, were derived. Greaves had led the way by finding out English weights and measures from the Egyptian pyramid. All particular pursuits have their peculiarities: that of the metrologists has been to imagine some grand and mysterious connection between existing measures

Paris, 1780. On the measurement of the earth on which the metre depends, see TRIGONOMETRICAL SURVEY. The system of measures derived from this great operation was introduced in 1795 (by the law of 18 Germinal, An III., or, to speak intelligibly, March, 1795): not that the survey was then completed, but because, in the hurry to get rid of the old system, it was decided to introduce a "mètre provisoire" obtained from the existing surveys. The definitive metrical system was introduced in 1799, but it was found impossible to drive out the old subdivisions; accordingly, in 1812, the "système usuel." as it was called, was allowed* to be engrafted upon the metrical system; in which the measures, &c., were taken from the metrical system, but with the ancient subdivisions adapted to them. Even this was very far from entirely driving out the old system. In 1837 a law was passed ordaining that from and after the 1st of January, 1840, no other weights nor measures should be used except those of the pure metrical system, and this law seems to have been effective. In the ancient French system the *pied de Roi* was 12·7892 English inches, the aune (at Paris) 46·85 of the same. The toise was 6 feet. For the itinerary measures see MILE. The *arpent d'ordonnance* was 1 acre, 1 rood, 2 perches (English); the *arpent commun* 1 acre, 7 perches, the *arpent de Paris* 3 roods, 15 perches, English. The *acre de Normandie* was 2 acres, 2 perches, English. For measuring liquids, the pinte was less than the English quart by its 61st part. Two boissons made a demisetier, 2 demisetiers a chopine, 2 chopines a pinte, 2 pintes a quarte, 4 quartes a setier, 36 setiers a muid (70·8 English gallons). For grain, 16 litrons made a boisseau, 3 boisseaux a minot, 2 minots a mine, 2 mines a setier, 12 setiers a muid. The minot was 1·108 English bushels. The principal weight, called *poids de marc*, was the livre of 9216 French grains, or 7555 English grains; 72 grains made one gros, 8 gros an ounce, 8 ounces a marc, 2 marcs a livre. The apothecaries divided the ounce into 2 duelles, the duelle into 4 sciliques, and also into 6 sextules and into 8 drachms, the drachm into 3 scruples, and therefore the scruple into 12 grains.

The new system is called metrical, as derived from the measurement of the earth. Its first measure, the metre, is presumed to be the ten-millionth part of a line drawn from the pole to the equator, and is 39·37079 English inches. All the multiples and subdivisions of every measure are decimal, and are formed by the same prefixes. For 10, 100, 1000, and 10,000, the syllables *Deca*, *Hecto*, *Kilo*, and *Myria* are prefixed; and for tenths, hundredths, thousandths, the syllables *Deci*, *Centi*, *Milli*. Latin† prefixes indicate division, Greek prefixes multiplication. Thus the hectometre is 100 metres, and the centimetre the hundredth part of a metre. The metre being thus settled, the other fundamental measures are formed as follows:—For surface or area, the *Are*, which is a decametre square, or 100 square metres, or ·02471143 of an English acre, or 3·9538 English perches.

For solidity, the *stere*, or cubic meter, 35·32 cubic feet English, or 220·09687 imperial gallons English.

For liquid measures, the *litre*, or cubic decimetre, ·22009687 of an imperial gallon, or a very little more than a pint and three-quarters English.

For weight, the *gramme*, a cubic centimetre of distilled water at the freezing-point, ·00220606 of an English pound averdupois, or 15·442 grains‡ English. The kilogramme is threfore 2·2 pounds averdupois, or, roughly, 50 kilogrammes make a hundredweight. The franc, the unit of money, is divided into 10 decimes, and each decime into 10 centimes. The sous is therefore 5 centimes. The advantage of the whole system, *when established*, is so great, that all who are fully aware of it, long for the introduction of a similar one into our own country. A Frenchman, when told that a kilogramme costs 253 francs 74 centimes, sees at once that a gramme costs 25 centimes and $\frac{374}{1000}$ths of a centime. An Englishman, wanting to know the price of an ounce when a hundredweight costs 253*l.* 14*s.* 10*d.*, must go through the whole of the following process:—

```
 112            253l. 14s. 10d.
   8               20
 ———              ————
 896     1792)5074(2
   2             3584
————             ————
1792             1490
                   12
                 —————
         1792)17890(10
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to get 2*s.* 10*d.* the answer.

The *système usuel*, now abolished, was as follows, the divisions being those of the old system. The toise was 2 metres, and the foot its sixth part. The aune was 3 feet 11¼ inches English. The boisseau was one-eighth of the hectolitre: the litron was 1·074 Paris pintes. The livre was 500 grammes. The arpent was that of the old system.

It is not in our limits to give a complete list of the weights and measures of foreign* countries. We have selected accordingly a ber of places from the smaller works on exchange operations, pre that the best choice we can make is that which includes th important countries or spots which have large money-dealings w own country. All the weights, &c. named have been taken† i places from Kelly's 'Cambist.' All the English measures are imperial (the gallons being reduced by ourselves into imperial g and each measure is given in English measures.

Austria.—The metrical system is introduced in the Ita minions. In Austria Proper, gold and silver are weighed Vienna marc of 4333 grains. The pfund is 1·235 pounds aver the metzen is 1·691 bushels. The eimer is 12·444 gallons. T is 12·45 inches: the ell, 30·66 inches. The joch is 1 acre, 1 r perches.

Bavaria.—The Augsburg marc is 3643 grains; 24 lb. com weight is 25 lb. averdupois; and 24 lb. carriers' weight is 2 dupois, nearly. The metzen is 1·515 bushels; the fuder (16 m 31·24 bushels. The foot (half the short ell) is 11·667 inche long ell is 24 inches.

Bremen.—For gold and silver, as at Hamburg. The com pound is 1·098 pounds averdupois. The last is 78·217 bushels ohm is 31·562 gallons. The foot, or half-ell, is 11·38 inches.

Colonies.—Follow in general the weights and measures of the country, except where they have passed under other governm which case there is usually a mixture of the two.

Constantinople.—The chequee is 4957 grains. The oke is pounds averdupois. The killow (dry) is 7·296 gallons. The 1·150 gallons. The pike is 27 inches. The measures of Tur very imperfectly known.

Denmark.—The pound for gold and silver is 7266 grains. commercial pound is 1·1028 pounds averdupois. The barrel is bushels. The viertel is 1·701 gallons. The foot, or half-ell Rhineland foot of 12·356 English inches. The toende of 5½ acres.

Florence and Leghorn.—The cantaro is 150 pounds of ·74864 p averdupois each. The stajo is ·6702 bushel. The barile is gallons. The braccio is 22·98 English inches. The saccata is 1 36 perches.

Frankfort.—For gold and silver, the Cologne marc. The com pound is 1·03 pounds averdupois. The centner is 112·25 pounds dupois. The malter is 2·9705 bushels. The ohm is 32·454 g The foot is 11·27 inches; the ell, 21·24 inches.

Geneva.—The mark is 3785 grains. The *poids fort* is 1·214 p averdupois; the *poids foible* one-sixth less. The coupe is bushels. The setier is 99·53 gallons. The foot is 19·2 inches. acre is 1 acre, 1 rood, 4 perches.

Genoa.—The pound *sottile* for gold and silver is 4891·5 grains. pound *grosso* is ·76875 pounds averdupois. The mina is 3·321 bus The mezzarola is 32·57 gallons. The palmo is 9·725 inches.

Hamburg.—The Cologne marc is 3608 grains. The pound tr two marcs. The commercial pound is 1·068 pounds averdupois. last of wheat (30 scheffels) is 10·9 quarters; the ahm is 31·85 g The foot is 11·289 inches. The scheffel (quantity usually sown a scheffel) of land is 1 acre 6 perches.

Holland.—The marc is 3798 grains. The pound is two marcs; the commercial pound is 1·0893 pounds averdupois. The last (vari divided) is 10·231 quarters. The aam (256 pints) is 34·16 gall The Rhineland foot is 12·36 inches. There are several ells of 27 inches. The Rhineland perch is 12 Rhineland feet, and the Rh land morgen or acre is 2 acres 16 perches.

Ionian Islands.—The weights and measures are mostly Venetian a Turkish.

Lübeck.—For gold and silver, as at Hamburg. The commer pound is 1·0685 pounds averdupois. The scheffel is ·92 bushels. Th ahm is 31·85 gallons. The foot, or half-ell, is 11·346 inches.

Malta.—The pound for gold and silver is 4886 grains. The commercial pound is 1·745 pounds averdupois. The salma is 7·968 bushels The foot is 11·167 inches. The canna (8 palmi) is 81·9 inches.

Milan.—The mark is 3627 grains. The pound *sottile* is ·7206 pounds averdupois; the pound *grosso* is 1·682 pounds averdupois. The mo (32 quartari) is 4·0234 bushels. The brenta (12 quartari) is 15 gallons. The braccio is 23·42 inches. The metrical system is al introduced, with Italian names.

Naples.—The pound for gold and silver is 4950 grains. The canta *grosso* is 196·5 pounds averdupois, the cantaro *piccolo* 106 pounds av dupois. The tomolo is 1·407 bushels. The barile is 9·172 gallons The palmo is 10·38 inches. The moggio is 3 roods 12 perches.

Netherlands.—Since 1820 the French metrical system has been in use, with Flemish names.

Portugal.—The marc is 3541·5 grains. The commercial pound is

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and a body of science which they say has been forgotten, but which they have never shown to have had existence.

[*] In 1816 it was enforced, decimal division being prohibited in retail business.

[†] The Latin prefixes suit the French language well enough: the Greek ones are incongruous and unsightly. Nor has the system been kept to entirely; the centigrade thermometer ought to have been *hectograde*.

[‡] Dr. Kelly ('Cambist,' i. 141) makes it 15·434 grains, for which he gives reasons.

[*] There is a large list of the fundamental measures of length, which are those most wanted, in 'Table of Continental Lineal and Square Measures,' by W. Woolhouse (London, Weale, 1836).

[†] We find the weights, &c., in the works from which the list of places was taken, rather different from those in Dr. Kelly's work. But the latter work is the best authority, and nothing but evidence can alter any weight or measure given in it. When a standard work exists in any language, it is absurd in any second-rate writer to differ from it without stating why.

1·0119 pounds averdupois. The moyo is 22·39 bushels. The almude is 3·6407 gallons. The foot is 12·944 inches.

Prussia.—(New system, established 1816.) The Cologne[*] marc is 3609 grains. Two marcs are a commercial pound, or 1·0811 pounds averdupois. The scheffel is 1·5116 bushels. The eimer is 15·11 gallons. The foot is 12·356 inches; the ell, two-thirds of a metre. The morgen, or acre, is 2 roods 21 perches.

Rome.—The pound is 5234 grains, or ·7477 pound averdupois. The rubbio (4 quarte) is 8·1012 bushels. The barile (32 boccali) is 12·841 gallons. The foot is 11·72 inches. The builders' canna, of 10 palms, is 87·96 inches.

Russia.—There is but one pound, ·9026 of a pound averdupois. The pood is 36 lb. averdupois. The chertwert is 5·7698 bushels. The vedro is 2·7048 gallons. The inch is the English one; the arshine is 28 inches; the foot is 13¾ inches; but the English foot is in common use. The dessetina is 2 acres, 2 roods, 32 perches.

Saxony.—For gold and silver, the Cologne marc. The commercial pound is 1·0294 lb. averdupois. The Dresden wispel (24 scheffels) is 69·85 bushels; the Leipzic wispel, 91·747 bushels. The Dresden eimer is 14·89 gallons; the Leipzic eimer 16·75 gallons. The Dresden foot is 11·14 inches; the Leipzic foot is 11·13 inches. The acre is 1 acre, 1 rood, 18 perches.

Sicily.—The pound is 7 pounds averdupois. The cantaro grosso is 192·5 pounds averdupois; the cantaro sottile is 175 lb. averdupois. The salma grossa is 9·46 bushels; the salma generale 7·59 bushels. The salma of wine is 19·23 litres. The palmo is 9·5 inches.

Smyrna.—The chequee is 4958 grains. The rottolo is 1·2748 pounds averdupois. The killow is 11·3 gallons. The pike is 27 inches.

Spain.—The Castilian marc for gold and silver is 4800 grains. The commercial pound is 1·0144 pounds averdupois. The fanega is 1·55 bushels. The arroba of wine is 3·538 gallons. The foot is 11·128 inches: the vara is 33·384 inches. The fanegada (for cornland) is 1 acre, 21 perches.

Sweden.—The Mint marc is 3252 grains. The commercial pound is ·9376 lb. averdupois. The dry tunna is 4·028 bushels; the liquid tunna is 48 kanns of ·5756 gallons each. The foot, or half-ell, is 11·684 inches. The tunneland is 1 acre, 35 perches.

United States.—The weights and measures are those of England before the late alterations.

Venice—The marc for gold and silver is 3681·5 grains. The pound *peso grosso* is 1·0518 lb. averdupois. The pound *peso sottile* is ·664 pound averdupois. The stajo is 2·2 bushels. The anfora is 114·1 gallons. The braccio for woollen is 26·61 inches; for silk, 24·8 inches. The foot is 13·68 inches.

We now proceed to the weights and measures of the ancients, taking first 'the relations 'of the various denominations to one another, and afterwards the fundamental comparisons of their values with the modern weights and measures.

The Romans had a mode of dividing the as or libra which they transferred upon occasion to any unit. The whole, whether an as or anything else, consisted of twelve unciæ, so that the uncia became little more than a name for the twelfth part. The division stood thus—

1½ unciæ	was	Sescuncia, or Sescunx.
2	„	Sextans (a sixth).
3	„	Quadrans (a fourth), or Teruncius.
4	„	Triens (a third).
5	„	Quincunx.
6	„	Semis, or Semissis (a half).
7	„	Septunx.
8	„	Bes, or Bessis.
9	„	Dodrans.
10	„	Dextans, or Decuncis.
11	„	Deunx.

The libra of weight was thus subdivided:—3 siliquæ, one obolus; 2 oboli, one scrupulum; 4 scrupula, one sextula; 6 scrupula, one sicilicus; 8 scrupula, one duella; 3 duellæ, one uncia; 12 unciæ, one libra. In later times the uncia was divided into 8 drachmæ of 3 scrupula each. This mode of dividing an integer into 288 scrupula runs through other branches of their system, and is also used in subdivision of a unit. The obolus in the preceding system rather belongs to a later period in which the Greek divisions were introduced, the ounce being made 8 drachmæ of 3 scrupula or 6 oboli each. The uncia appears (as *οὐγγία*) in the later Greek writers.

In the measures of length the pes, or foot, was divided not only into 12 unciæ, but also into 16 digiti. In such Roman foot-rules as have been found, all have the digital division, some both, but none the uncial without the digital. And 4 digiti are one palmus; 4 palmi, one pes; 1¼ pedes, one palmipes; 1½ pedes, one cubitus; 2½ pedes, one gradus; 2 gradus, or 5 pedes, one passus; 2 passus, one decempeda; 12 decempedæ, one actus;[†] 1000 passus, one milliare.

The jugerum was an area of which the scrupulum (or 288th part) was the square decempeda, or 100 square feet. It was frequently divided uncially, and also as follows:—36 scrupula made 1 clima, 4 climata, 1 actus quadratus; 2 actus quadrati, 1 jugerum; 2 jugera, 1 heredium; 100 heredia, 1 centuria; 4 centuriæ, 1 saltus. The actus minimus was 480 square feet. The versus was 10,000 square feet. The aripennis (whence *arpent*) was a Gallic measure which Columella defines as semi-jugerum, but whether of Romans or Gauls is not clear.

The amphora, or quadrantal,[*] for liquid measure, was a cubic foot: 4 ligulæ made 1 cyathus; 6 ligulæ, 1 acetabulum; 2 acetabula, 1 quartarius; 2 quartarii, 1 hemina; 2 heminæ, 1 sextarius; 6 sextarii, 1 congius; 4 congii, 1 urna; 2 urnæ, 1 amphora; 20 amphoræ, 1 culeus. In Galen the cochleare is the tenth of a ligula.

The modius, or modium, of dry measure, was 16 sextarii, or the third part of the amphora, or cubic foot. The sextarius was divided in the same manner as in liquid measure. The concha is mentioned as a smaller measure than the ligula.

The Greek weights have been discussed in the article Talent. Six *ὀβολοι* make one *δραχμη*; 100 *δραχμαι*, one *μνα* (mina); 60 *μναι*, one *ταλαντον*. The *χαλκος* and the *λεπτον* are mentioned as subdivisions of the *ὀβολος*, but are not generally recognised.

As to length, the *πους*, or foot, was thus divided:—4 *δακτυλοι* make one *παλαιστη*; 12 *δακτυλοι*, one *σπιθαμη*; 4 *παλαισται*, one *πους*; 1½ *ποδες*, one *πηχυς*; 4 *πηχεις*, one *ὀργυια*; 100 *ποδες*, one *πλεθρον*; 6 *πλεθρα*, or 600 *ποδες*, one *σταδιον*. [Stadium.] The *δοχμη* is the *παλαιστη* in some writers, the *σπιθαμη* in others. The *παλαιστη* is also called *δακτυλοδοχμη* and *δωρον*. The *λιχας* is 10 *δακτυλοι*, the *ὀρθοδωρον* is 11 *δακτυλοι*, the *πυγμη* 18, and the *πυγων* 20 *δακτυλοι*. The *διχας* is half a *πους*, the *βημα* is 2½ *ποδες*. The *ξυλον* is 4½ *ποδες*, and the *καλαμος* 10 *ποδες*. The *σταδιον* was once called *αὐλος*, and the *διαυλος* is 2 *σταδια*. The *σταδιον ἱππικον* is 4 *σταδια*, and the *δολιχος* is 12 *σταδια* generally, but is variously used. We must also mention the *κονδυλος* of 2 *δακτυλοι*, and the *ἁμμα* of 60 *ποδες*. The Greeks have taken the *σχοινος* (variously described) from the Egyptians, the *μιλιον* from the Romans, and the *παρασαγγης*, which is 30 stadia, according to Herodotus and Xenophon, from the Persians. The *πους φιλεταιριος*, or Philetærian foot, though used by Greek writers, is not originally Greek, and is said to be longer by a fifth than the Roman foot. All writers agree that the common Greek *πους* is longer than the Roman foot by the 24th part of the latter.

The *πλεθρον* in square measure was a square of the side of a *πλεθρον* in length, or 10,000 square *ποδες*. The *ἀρουρα* was the fourth part of the *πλεθρον*; but the Egyptian *ἄρουρα* mentioned by Herodotus is the square of 100 Egyptian cubits.

In liquid measure, 2 *κοχλιαρια* make one *χημη*; 2½ *κοχλιαρια*, one *μυστρον*; 2 *μυστρα*, one *κογχη*; 2 *κογχαι*, one *κυαθος*; 3 *κογχαι*, one *ὀξυβαφον*; 2 *ὀξυβαφα*, one *τεταρτον*; 2 *τεταρτα*, one *κοτυλη*; 2 *κοτυλαι*, one *ξεστης*; 6 *ξεσται*, one *χους*; 12 *χοες*, one *μετρητης*. The *μετρητης* is said to have been an amphora and a half, and the *κυαθος* to have contained 10 drachms of wine. The *λαγυνος*, or *λαγηνος*, was the same as the *χους*. There were also the *χημη γεωργικη* and the *μυστρον γεωργικον*, rural measures. The *μετρητης* was also called *ἀμφορευς* and *καδος*.

In dry measures, the *μεδιμνος* was one-third larger than the *μετρητης* (or was two Roman amphoræ), and was thus divided:—Ten *κοχλιαρια* made one *κυαθος*; 15 *κοχλιαρια*, one *ὀξυβαφον*; 4 *ὀξυβαφα*, one *κοτυλη*; 2 *κοτυλαι*, one *ξεστης*; 2 *ξεσται*, one *χοινιξ*; 4 *χοινικες*, one *ἡμιεκτον*; 2 *ἡμιεκτα*, one *ἑκτος*; 6 *ἑκτοι*, one *μεδιμνος*. There are various descriptions of the *χοινιξ*, from which it may be that there are several measures of the name. The Greeks mention the Persian *ἀχανη* of 45 *μεδιμνοι*, the *ἀρταβη*, of one *μεδιμνος*, and the *καπιθη* of 2 *χοινικες*. The Bœotian *κοφινος* is 3 *χοες*: the Homeric *αδδιξ* is 4 *χοινικες*; the *μαρις* is 6 *κοτυλαι*; the *ἀλαβαστρον*[†] is the *κοτυλη*.

The following measures are identical in pairs, if the *μεδιμνος* be two amphoræ:—The *χους* and the congius; the *ξεστης* and the sextarius; the *κοτυλη* and the hemina; the *τεταρτον* and the quartarius; the *ὀξυβαφον* and the acetabulum; the *κυαθος* and the cyathus.

All the Greek measures above given are Attic: there are some variations of description which, if not erroneous, probably belong to other parts of Greece. It is customary to give the Greek and Roman measures in two collections, without any attempt to distinguish the times at which they were in use; so that Homer and Athenæus, or Herodotus and Galen, may appear as authorities in the same set. There are many other names of measures noted by different writers, some of which are but synonymes of some of those above mentioned, and of others it may be doubted whether they were really names of recognised measures. If the writers of our day were compared in isolated passages as closely as those of the ancients, we might probably have a great many measures made for us of which we know nothing: the shells which the grocers use would have good chance of a permanent establishment, and their paper bags could not possibly escape.

The Hebrew measures, though tolerably well settled in their proportions, are very imperfectly known as to their absolute magnitudes.

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[*] This weight, established by Charles V. as the standard of the precious metals throughout Germany, has varied in different places from 3606 to 3612 grains.

[†] The actus is described as the length of a furrow. If our furlong had been (as some would suppose) a furrow long, it would have been nearer to the Roman actus, not one-eighth of a mile.

[*] The term quadratus seems to have applied to cubes as well as squares among the Romans.

[†] This word is translated in two of the gospels (Mark xiv. 3; Luke vii. 37) *an alabaster box;* Epiphanius is the authority for the measure, which there is no doubt took its rise from the circumstance of perfumes being commonly inclosed in alabaster boxes of one size.

We shall only give here the usual summary, and shall then give some account of the mode of determining the actual magnitude of the Greek and Roman measures. With regard to these Hebrew measures, much uncertainty prevails; the authorities are by no means so numerous as those for the other ancient measures, nor has the subject received so much discussion.

The cubic was about 22 inches; 4 digits make 1 palm; 3 palms, 1 span; 2 spans, 1 cubit; 4 cubits, 1 fathom; 6 cubits, 1 reed (Kaneh); 8 cubits, 1 pole (Arabian); 80 cubits, 1 measuring-line;* 400 cubits 1 stadium; 5 stadia, a Sabbath-day's journey; 10 stadia, a mile; 24 miles, a day's journey.

In liquid measures, the bath, or ephah, of about 6¼ imperial gallons, is thus divided:—Four logs make 1 cab, 3 cabs, 1 bin; 2 hins, 1 seah; 3 seahs, 1 ephah. The caph is three-fourths of the log. For dry measures, besides the cab, seah, and ephah, 5 ephahs make 1 letech; 2 letech, 1 Chomer, or Homer. The gomer is the tenth of the seah.

For weight, 60 shekels make one maneh; 50 maneh, 1 talent of 93·75 pounds averdupois.

We now come to the comparison of the Greek and Roman measures with our own. The Roman foot, the most important of all, has been determined in the following † ways:—1. By feet laid down on sepulchral monuments. 2. By foot-rules obtained in the ruins of Rome and elsewhere. 3. By the distance of mile-stones. 4. By the distance of places. 5. By specimens of the congius. 6. By some obelisks. 7. By the dimensions of buildings. The results are given in lines of 144 to the Parisian foot, and as many dissertations on this subject make great use of the line, it will be convenient to give a table of its multiples in terms of the English inch.

One line ($\frac{1}{12}$ inch French) is .	·08881378	English inch.
2 lines are	·17762756	„
3 „	·26644134	„
4 „	·35525512	„
5 „	·44406890	„
6 „	·53288268	„
7 „	·62169646	„
8 „	·71051024	„
9 „	·79932402	„

129·484 lines are 11½ English inches.

The *sepulchral* feet are:—1. That marked on the tomb of one Statilius,‡ found in the Vatican garden in the 16th century; 2. That found on the tomb of Cneius Cossutius (Vitruvius mentions an architect of that name), dug up in the garden of Angelo Colozzi § before 1516; 3. That on the tomb of M. Æbutius; 4. That on a monument without inscription, given by the Marquis Capponi to the Capitoline Museum at Rome. Taking the means of such trustworthy measures as have been made of these different feet, it appears that the Statilian foot is 131·17 Paris lines; the Cossutian, or Colotian, 130·59 lines; the Æbutian 131·14 lines; and the Capponian 130·80 lines.

The first foot-rule was measured by Lucas Pætus, 'De Mensuris et Ponderibus Romanis et Græcis,' Venice, 1573, who found three of them agreeing with each other so far as his means of comparing them went, a copy of which he caused to be engraved on stone and placed in the Capitoline Museum. This was called the *Capitoline foot*, and was frequently regarded as conclusive. Pætus himself makes the foot amount to 128·7 lines; but there is reason to suppose either that his measures are too short or that the standard to which he referred them has been mistaken; for others make his own Capitoline foot to be 130·5 lines. Two other foot-rules give 128·75 and 130·03 lines. There was a porphyry column at Rome (now lost) marked *ποδ. θ*, which was certainly meant for nine Roman feet. An editor of Vitruvius, Philander (1552), makes the Roman foot to be, from this column, 131·63 lines; but Pætus makes it only 130·03. Other foot-rules have been made to give 130·5, 130·93, 132·89, 130·56, 129·24, 131·16, 130·66. Some of these are different measures of the same rule.

Very few consecutive milestones have been found from which to deduce the foot. From one mile in the Appian way, and from two different ones between Nismes and Beaucaire, the foot has been deduced to be 130·60, 130·29, and 130·51 lines. From various recorded distances between towns, subject to the difficulty of knowing precisely from what parts of them the miles were measured, the foot has been found to be 132·34, 128·42, 130·99, 129·31, 132·55 lines. D'Anville, from a collection of such measures, fixes it at 130·8 lines.

A specimen of the congius is yet remaining, which, by an inscription, is declared to have been placed in the Capitol by Vespasian as a standard. The congius is the eighth part of the amphora, or cubic foot. By ascertaining the weight of water which this contains, the foot was estimated by various observers at 131·15, 133·21, and 132·44 lines. From the length of the foot drawn upon the congius [illegible] been obtained 132·8, 133·5 lines. From another congius [illegible] Paris, Auzout found 134·18 lines for the Roman foot.

There are two obelisks at Rome, which were brought by [illegible] from Heliopolis. Pliny gives the height of these in feet, or [illegible] the height of the higher and the defect of the lower from it. [illegible] ment proves that, with respect to the higher, the number [illegible] must be corrupt; but from his difference between the two, [illegible] pared with the measured difference, the Roman foot is 137·19 [illegible]

The method of ascertaining the foot by buildings is as [illegible] Any remarkable length, such as that of the whole front of a [illegible] being known nearly in Roman feet, is presumed to be [illegible] number of feet which it must be nearly. This supposes [illegible] Roman architects were in the habit of choosing exact numbers [illegible] when there was no particular reason for breaking a foot. [illegible] ('Phil. Trans.,' 1760) proceeds in the manner of which the [illegible] is an instance:—He finds the distances between the [illegible] the temple of *Fortuna virilis* to be 9·7106 English feet. If [illegible] an exact number of Roman feet, it must be 10; we know [illegible] beforehand of the Roman foot to say it cannot be 9 or 11. [illegible] quently, if the distance between these columns be a whole [illegible] feet, the foot must be ·97106 of the English foot. By [illegible] this sort, Greaves found 131·50 lines, La Hire 131·0 and [illegible] Condamine 130·9, Jacquier 131·08 and 131·14. Raper, who [illegible] into this subject than the others, found by different buildings [illegible] 131·60, 131·62, 131·11, 131·16, 131·05, 131·16, 131·05, and [illegible] the mean. Wurm, from the Verona amphitheatre, adds [illegible] Raper thought he observed that the buildings subsequent to the [illegible] of Titus give a shorter foot than their predecessors: from [illegible] gets 130·75, 130·33, 130·34, with a mean of *130·34*. He [illegible] change to the destruction of the Capitol (where the standards [illegible] kept) in the time of Vitellius.

From all these data Raper's average, adopted by Wurm, is [illegible] French lines for the ancient foot, or 11·648 English inches or [illegible] English feet. But Sir G. Shuckburgh made a careful review [illegible] three best modes of obtaining the required result, namely, rules, [illegible]ings, and tombs, and obtained ·9672, ·9681, ·9696 of a foot [illegible] (Young's 'Lectures,' ii. 153.) The mean of these is ·9683 feet, [illegible] 11·6196 inches. Again, if we take a mean of the results given [illegible] others, namely, Bernard ·970, Picard and Greaves ·967, Folkes [illegible] Raper ·970, we have also ·9683. We take then the Roman foot [illegible] 11·62 English inches, which is represented far within the [illegible] limits of error by the following:—61 English feet make 63 [illegible] feet. We are well aware that eminent authorities of late years [illegible] 11·65 inches for the Roman foot, but we like to keep as near to the foot-rules as we can, consistently with giving due weight to other modes. Indeed, the question between 11·62 and 11·65 cannot be settled by authority, but must be decided by closer appreciation than has yet been made of the probabilities of the different methods.

The Roman measures of length may thus be considered, we fully believe, to be as well known to us as they were to themselves. The same cannot be said of the measures of weight. All writers agree that the amphora, or cubic foot, weighs 80 pounds of wine; but it is also said that they considered wine to be of the same weight as water. We have no means of ascertaining the specific gravities of their wines; those of our own vary from ·99 to 1·04, water being taken as 1. But there is one very obvious consideration which, we believe, has escaped notice. No metrologist has given the Romans credit for seeing that water would do just as well to make comparisons and adjust standards by, as wine, believing, as they did, that both are of the same weight. If we suppose then that they preferred to spill water rather than wine, and assume 11·62 inches for the foot, we have 1568·984 cubic inches* English, in the amphora, or 5·6586 imperial gallons, or 56·586 pounds averdupois of water. If the Roman pound be the 80th part of this, it is ·7073 pounds averdupois, or ·8595 pounds troy. This is 4951 grains, or 6039½ French grains. Now, according to Wurm, Budæus made it 7200 French grains, Capellus and Romé de L'Isle 6048, Auzout 6226, Eisenschmid 6216, Dupuis 6300, Leblanc and De la Nauze 6144, Paucton 6312, Arbuthnot 6395. Of these, those of Romé de L'Isle and La Nauze, which come the nearest to 6039½, were determined from weighing coins: but the most modern valuations deduced from coins give 5040 grains. On coins however we do not much rely. The congius of Vespasian, already mentioned, gave to different experimenters 6094, 6386, and 6276 Paris grains; but it is most probable that the capacity of this vessel has been somewhat increased by rust. There are also some ancient weights in stone or metal, preserved in different places, from which De L'Isle brings out 6071 and 6042 grains. But others make different results, whether from the coins or the weights; and the result of the whole seems to be, that the Roman pound cannot be more accurately stated than in the following words: "something more than seven-tenths of a pound averdupois." The Attic TALENT is said by many writers to be 80 Roman pounds. Now this being taken, as in the article cited, at 56·953 pounds averdupois, gives ·7119 of a pound averdupois. Between ·707 and ·712, or very near to one of these extremes, we have little doubt the truth really lies. Accordingly, the Roman uncia is much nearer to our ounce averdupois than to our ounce troy; and many metrologists have supposed that the former was originally the uncia.

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* Pathil, or Chebel; *σχοινος* in the Septuagint.

† In the historical account of the Roman foot we have followed J. P. Wurm, 'De Ponderum, &c. Rationibus apud Romanos et Græcos,' Stutgard, 1821, as to method, verifying several of his statements.

‡ We enumerate these, not for their importance, but because they are so frequently referred to.

§ The foot is figured in the work of Leonardus Portius, the first in which any attempt was made to restore the real Roman measures. It has no place nor date; but being printed by Joh. Frobenius, must be of Basel before 1527.

* To turn cubic inches into imperial gallons, multiply by 11 and by 2, divide by 6100, and, if worth while, from the result subtract its two hundred thousandth part.

We have never had any means of knowing whether the fundamental points of connection between the Greek and Roman measures are exact or only approximate. These are, that the foot is longer than the Roman by one twenty-fourth, and the Philetærian foot by one-fifth; that the *μετρητης* is an amphora and a half, and that the amphora of water or wine weighs an attic talent. Taking these relations for granted, we have for the Greek foot 12·10 English inches or 1·008 feet, for the Philetærian foot 13·94 inches, for the metretes 8·4879 gallons, and for the attic talent 56·586 pounds averdupois. There is one stadium left at Athens [Stadium] which is 630 English feet, giving for the Greek foot 1·05 feet English; but there is not much dependence to be placed on the measure. Such buildings as have been examined at Athens, in the manner already described, give as a mean 136·69 Paris lines, or 12·14 English inches. We may therefore say that the Greek foot was longer than the English one by the tenth part of an inch. The statements then as to the relations between the Greek and Roman measures appear to have been tolerably exact, and our knowledge of the relations between our measures and theirs, though not sufficient for scientific comparison, is abundantly exact for the purposes of the classical student, far more so than could have been expected to have been attainable by those who remember that for a long period all means of comparison were lost.*

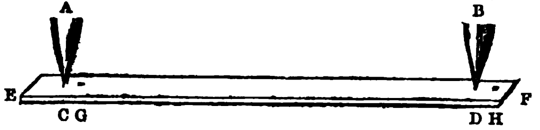
WEIGHTS AND MEASURES, STANDARD. In this article we separate from the general subject of Weights and Measures those preliminary considerations which refer to the manner in which weights and measures are verified and preserved, so far as they can be entered upon in a work partly of reference, partly of general information. We do not pretend to complete a scientific account, but shall be satisfied with preparing the unpractised reader to look with some degree of interest on the sources of more elaborate information to which we shall refer.

Measures are wanted for two distinct objects, the commercial and the scientific. The wants of natural philosophy have grown up within the last two centuries; while so early as Magna Charta it was one of the concessions to the grievances of the subject that there should be one weight and one measure throughout the land. But though a few acts of parliament were sufficient, in process of time, substantially to establish the political rights which that charter was intended to grant, hundreds of them, down to the present time, have been ineffectual in producing the use of one weight and one measure. Some of these we shall afterwards refer to [Weights, &c.]; in the meanwhile we have here only to state that, as may be supposed, this unity was for commercial, not scientific purposes; and that the resemblance of natural objects was supposed to be a sufficient reliance for obtaining it. Some of the old statutes expressly make the inch to be the length of three barleycorns, placed end to end, round and dry, from the middle of the ear. Standards were made, no doubt, from this definition; or at least it was supposed that if the existing standard should be lost, the barleycorns would enable its restoration to be effected. Our readers may smile at what they think so rude a contrivance; but the same principle, carried a little further, might be made very efficient in preserving a measure. Suppose for example, that the government were now to think it desirable to recover the three-barleycorn inch, or at least to invent one which should be capable of being recovered. They would put together not three barleycorns, but three thousand, or thirty thousand; or many different collections of three thousand or more. The average inch deduced from these would be capable of being recovered at any time from the same grain grown in the same soil. A commercial standard might be easily recovered from many different modes of proceeding: for example, the *average* height of the barometer at a given place throughout any period of five years is so nearly the same from one five years to another, that a commercial standard might be sufficiently well obtained from it. It would be of little consequence if the yard were wrongly recovered by one-hundredth or even one-tenth of an inch, in any matter of buying and selling.

It is the *scientific* standard at which the government has been aiming during the last century. The object here is, first, to measure the old standards to the utmost accuracy of which our senses, assisted by microscopes, are capable; secondly, to discover the means of reconstructing a lost standard. In the more delicate operations of natural philosophy and astronomy, our knowledge cannot go down to posterity, unless they know within the thousandth of an inch what it is that we call a yard. The public at large has never understood the reason why so much trouble has been taken; and perhaps the members of different administrations, while trusting such investigations to men of science, and relying on them for the whole conduct of the matter, may have wondered at the great difficulty which there seemed to be in the way of furnishing the shopkeepers of all generations with the yard measures and pound weights of the same values. It is our principal object in this article to endeavour to point out the nature of these difficulties, and the extent to which they have been overcome: it being remembered however that the object is scientific, not commercial, and that the standard of length is chosen as the most important illustration.

To elucidate the *principle* merely of the manner in which scales are compared, we must first show how it is that very small lengths can be measured. A screw can be very accurately constructed, say with threads one-twentieth of an inch apart: if this screw be the axis of a circular plate, which turns with it, and the edge of the plate be divided into 100 parts, each of these parts will be very perceptible, if the plate be three-quarters of an inch or more in diameter, and it will not be difficult to estimate the half or quarter of one of the divisions. Let there be an index attached to the frame, which does not move with the screw, by which it may be seen, when the plate (and with it the screw) is turned, how many divisions it is turned through. Now since a whole turn of the screw moves the end of it forward through one-twentieth of an inch, a motion of the plate which passes one of the divisions over the index, or the hundredth part of a turn, sends the end of the screw forward through only one two-thousandth of an inch, and a quarter of a division answers to one eight-thousandth of an inch. Suppose a couple of such screws, each of which is attached to a pointer, as in the following diagram, in which the pointers only are inserted, and one of the scales which are to be compared; the screws which move the pointers, and all the frame-work, being omitted. Observe also that this is not the apparatus employed, but only a convenient illustration of it.

It is supposed that A and B can be moved, by the screw motion, in such a manner that a motion so small as the eight-thousandth of an inch may be given to either. The scale at present used is E F, on which are two points, C and D, which are, or are supposed to be, exactly a yard asunder. Let the screws be moved until the ends of the pointers, which all but touch the scale, are exactly over C and D; then if the scale be removed, the length C D is retained in the distance between the points of the pointers. Now let another scale be introduced, and let its points be brought as near as may be, conveniently, to the pointers: it is supposed that the distances C D and G H are very nearly equal, for workmen used to the construction of mathematical instruments never fail in making two yard measures agree within a fiftieth of an inch. Perhaps the reader will say the point G might be brought *exactly* under the pointer A, and then the pointer B alone would show whether the present scale is shorter or longer than its predecessor: but as the pointer is much less cumbrous than the scale, it is easier and safer to put the scale in a convenient position than to attempt to place it in one exactly given. This being done, move the pointer A from C to G, and observe how many turns, or how much of a turn, of the screw, is required to do it: say it makes 87½ divisions of the plate pass the index. Also move the pointer B from D to H, which makes, say, 97¾ divisions of the plate pass the index. Now we obviously have



$$GH = CD + DH - CG;$$

and since D H is longer than C G, it appears that G H exceeds C D by the excess of D H over C G, answering to 97¾ − 87½, or 10¼ divisions of the plate, being 10¼ times the two-thousandth of an inch, or ·005125 of an inch. This experiment may be repeated any number of times, and as may be expected, the results will not agree, since it is not to be supposed that any two persons, or the same person at two different times, will agree in their estimation of exact coincidence between the pointers and the ends of the scales. As in other cases, the averaging of the discordant results will bring out the truth very nearly.

The difference between the apparatus which was actually used in the next experiments and that above described was as follows. The pointers were Micrometer* microscopes, in which the intersection of two fine spider-threads, placed at the focus, was the point which was made, by a slow screw motion, to coincide with the centre of the (magnified) dot (or line) which formed the extremity of the scale. The micrometer head (the circular plate of the preceding illustration) was divided into 100 parts, each of which was found to be equivalent to one 20,000th of an inch; or a whole turn of the screw altered the position of the intersection of the spider's webs by one 200th of an inch. The magnifying power used was about 27 times in linear dimension. It was attempted, in each experiment, to estimate tenths of the divisions of the micrometer-head, or to attain† the 200,000th part of an inch. The apparatus is described in Mr. Baily's 'Report to the Royal Astronomical Society on their Standard Scale' (published in the ninth volume of their Memoirs), from which much of the present article is taken.

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* For further information on ancient weights, coins, and measures, the reader is referred to the following work, 'Metrologische Untersuchungen über Gewichte, Münzfüsse, und Masse des Alterthums in ihrem Zusammenhange, von August Boeckh,' Berlin, 1838; and to a review of this work in the 'Classical Museum,' No. 1, by Mr. Grote.

* The principle is the same as that of the beam compasses, and the apparatus might be called microscopic beam-compasses, or beam-microscopes.

† Every attempt at measurement strives to be ready for more than there is any reasonable hope of attaining. It is certainly not likely, at present, that even the mean of a large number of measures would settle the question within so small a quantity; but if ever the day shall arrive when the 200,000th of an inch is attainable, the previous attempts to obtain it will point out the cause of their own failure, and probably be a source of information.

The first attempts to be scientific in matters of measurement made in this country date from the beginning of the 17th century. Previously to this time men of information probably believed that the Roman and English foot were the same, and that the pound troy was deducible from the Roman Libra. Bishop Tonstal, in his Arithmetic (1522), where he only treats what is necessary for common life, "ad vitam communem transigendam necessaria," cites Columella on measures of length, and deduces the system of coinage from Budæus on the Roman As. The other writers of the same century pass over the mode of obtaining measures, as if it were perfectly fixed, and generally refer to the three-barleycorn inch as a standard. In the early part of the 17th century we find Oughtred ('Circles of Proportion,' pp. 55-57) referring to actual measures of the contents of the gallon made by the celebrated Briggs, and also by one William Twine, but taking the Roman foot as "very little less, if not exactly the same," as the English foot. Later in the century, Dr. Wybard ('Tactometria,' p. 268, published in 1650) gives an account of experiments, at which he was present, for the determination of the same gallon; and later still, in 1688, we have the experiment with the same object [GALLON], at which Flamsteed and Halley were present, which is referred to in the Report of the Committee of the House of Commons in 1758. As far as measurements are concerned, had it not been for Greaves [GREAVES, JOHN, in BIOG. DIV.], we might have summed up the efforts of the 17th century by saying they were mostly directed to finding, within one, how many cubic inches there were in the several gallons. Greaves first directed attention to the difference between the Roman foot and the English, by tolerably accurate determinations of the former. [WEIGHTS AND MEASURES.] He also attempted the investigation of the Roman weights, and must be considered as the earliest of the scientific metrologists. He was followed by Dr. Bernard [BERNARD, EDWARD, in BIOG. DIV.], whose treatise on ancient weights and measures (1685 and 1688) must have given a great impetus to the spirit of comparison. A work of this kind soon shows its consequences: Jeake's 'Arithmetic' (folio, 1696) contains a hundred pages on the subject. Towards the end of the century the measures of Auzout and Picard awakened attention to the comparison of standards in France. Both countries were thus prepared to desire some information from each other on the subject of their measures; and a communication took place in 1742 between the Royal Society and the Academy of Sciences for an interchange of standards. Then, for the first time, as far as we can learn, a yard was taken off on a brass rod from a standard kept in the Tower of London (which we believe is not now in existence). But the legal standard, usually so considered, was one which was kept at the Exchequer; there was another at the Guildhall, and another in the possession of the Clockmakers' Company. When these came to be compared with one another and with the Exchequer standard by Graham (who also laid down an Exchequer yard on the same brass rod), it appeared that the shortest and the longest differed by seven-hundredths of an inch, a little more than the height of an *o* or an *a* in this work. But had the difference been greater, it would not have mattered much, considering the way in which standards were to be used. In our own day, after nearly a century of communication between statesmen and philosophers on the subject of a uniform measure, Mr. Baily visited the Exchequer standard (from which the copies we shall presently mention were made), and his account (Report above cited, p. 146) is as follows:—"Since the preceding sheets were printed, I have had an opportunity of seeing this curious instrument, of which it is impossible at the present day to speak too much in derision or contempt. A common kitchen poker, filed at the ends in the rudest manner by the most bungling workman, would make as good a standard. It has been broken asunder, and the two pieces have been dovetailed together, but so badly that the joint is nearly as loose as that of a pair of tongs. The date of this fracture I could not ascertain, it having occurred beyond the memory or knowledge of any of the officers at the Exchequer. And yet, till within the last ten years, to the disgrace of this country, copies of this measure have been circulated all over Europe and America, with a parchment document accompanying them (charged with a stamp that costs 3*l*. 10*s*., exclusive of official fees), certifying that they are true copies of the English *standard*."

In 1758, a committee of the House of Commons began to investigate this subject, and was followed by another in 1759: both committees made full Reports. Both committees caused to be made, by Bird, a copy of the Royal Society's (or Graham's) copy of the Exchequer standard, and these copies, which remained in the official possession of the Speaker of the House of Commons, were called Bird's parliamentary standards of 1758 and 1760: it should be stated, however, that the latter was only a copy of the former. The Reports were agreed to by the House: a bill was brought in, according to their recommendation, namely, that Bird's standard of 1758 should be the national standard; but it was not carried through. A committee, appointed in 1790, did nothing, and the matter was thus abandoned. Private individuals and scientific societies began to provide themselves with standards: Sir G. Shuckburgh ('Phil. Trans.,' 1798) had one made by Troughton, which he compared with the parliamentary standards and others. Troughton made one for himself, and first introduced the micrometer microscopes into the comparisons; this last was made from one which Bird had made for the then assay-master of the Mint. Another was made for General Roy, and was used by him in the great survey; and a Bird's own private property, was in existence. Thus matters were until the year 1814, when the House of Commons again appointed a committee to consider the subject.

In the meanwhile however experimental philosophy had made great advances, and investigators began to look more at the successes of the past than at the new difficulties which those very successes had opened into view. As soon as the measurements of the earth began to be attended with some success, the French proposed a standard measure which should be the ten-millionth part of a quarter of the meridian, which last they hoped, by their great survey, to ascertain so exactly that no future measurement should make even a microscopic alteration of their new *metre*. In England the pendulum began to be considered a perfect instrument; and the second being determined invariably by the motion of the earth, it was thought that the length of the seconds' pendulum in a given latitude would be an invariable quantity which could always be recovered. The committee of 1814, on the evidence of Playfair and Wollaston, recommended that Bird's standard of 1760 should be the one adopted, and gave it as their opinion that the length of a seconds' pendulum in the latitude of London is 39·13047 inches, of which the above-named standard yard contains 36. Playfair and Wollaston hinted at the necessity of verifying this number, but the committee take it for granted, and assert that any expert watchmaker can make a seconds' pendulum, without stating how that pendulum is afterwards to be measured, nor at what temperature, pressure, &c. it is to be swung. They also state that a cubic foot of pure water at 56½ Fahr. weighs exactly 1000 ounces avoirdupois, as the connecting link between measures of weight and capacity. No bill was brought in consequence of this Report.

In 1819 the Prince Regent appointed a commission composed of Sir J. Banks, Sir G. Clerk, Davies Gilbert, Wollaston, Young, and Kater. This commission made three Reports, dated June 24, 1819, July 13, 1820, and March 31, 1821. In the first (we confine ourselves to matters affecting the standards) the standard yard recommended is that on the scale used by General Roy in the measurement of the Hounslow Heath base, and it was the opinion of the reporters that the mean solar seconds' pendulum in London, at the level of the sea, in a vacuum, and at 62° of Fahr., was 39·1372 inches of this scale. They also take 19 cubic inches of distilled water at 50° to be exactly 10 ounces troy. In the Second Report, they announce that an error has been discovered in their standard, and they propose that Bird's parliamentary scale of 1760 shall be the standard, the seconds' pendulum being 39·13929 inches. In the Third Report, they announce, by new experiments, that a cubic inch of distilled water at 62° is 252·72 grains of the standard pound of 1758, when weighed in a vacuum. The House of Commons again appointed a committee in 1821, to which these Reports were submitted: this committee agreed with the commissioners, and a bill was introduced in 1823. A petition from the Chamber of Commerce at Glasgow to the House of Lords occasioned an investigation in that House also; Dr. Kelly, one of the witnesses before the committee, called attention to the known effects of variety of attraction on the pendulum, as shown by Captain Kater's own observations, and to the insufficient manner in which the level of the sea was known: and his opinion was that of few others at the time, though now nearly universally received, namely, that "nature seems to refuse invariable standards; for, as science advances, difficulties are found to multiply, or at least they become more perceptible, and some appear insuperable." The House of Lords adjourned the question over till 1824; when the act 5 Geo. IV. c. 74, was passed, from which extracts will presently be made. This act was to take effect May 1, 1825, but in the March of that year 6 Geo. IV. c. 12, was passed, deferring the operation of the preceding act till January 1, 1826. There was an inquiry before the House of Commons in 1834, which ended in the statute of 4 & 5 Will. IV. c. 49, and another inquiry before the same House in 1835, which ended in 5 & 6 Will. IV. c. 63, repealing the former act and substituting new provisions. These last acts however contain nothing with reference to the standards, except the following excellent wind-up of the chequered and ill understood legislation upon weights and measures. The Houses of Parliament were burnt in 1834, and with them Bird's standards of 1758 and 1760 (the last *the* standard). Nevertheless 5 & 6 Will. IV. c. 63, passed after the fire, takes no notice of the destruction of the standard, but refers to it as still in existence. Seven years* have since elapsed, but we are not aware of the legislature having yet swung the pendulum to recover the lost measure.

As to the standards, the act prescribes as follows:—

1. The straight line or distance between the centres of the two points in the gold studs in the straight brass rod now in the custody of the clerk of the House of Commons, whereon the words and figures "Standard yard, 1760" are engraved, shall be the original and genuine standard of that measure of length or lineal extension called a yard … the brass being at the temperature of sixty-two degrees of Fahrenheit's

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* This was written by Mr. Sheepshanks in 1841.

thermometer. . . . . The act goes on in many words to say that the pendulum vibrating seconds of mean time in the latitude of London* in a vacuum at the level of the sea is 39·1393 inches of the said standard.

2. The standard brass weight of one pound troy weight, made in the year 1758, now in the custody of the clerk of the House of Commons, shall be the original and genuine standard measure of weight. . . . The act goes on to say that the cubic inch of distilled water, weighed in air by brass weights, at 62° of Fahr., the barometer being at 30 inches, is equal to 252·458 grains.

It happened fortunately for the scientific standard, that about the year 1832 the council of the Royal Astronomical Society caused a scale to be constructed for themselves, and obtained permission of the Speaker of the House of Commons to compare it with Bird's two standards, which was done in the beginning of 1834, by a much more extensive set of experiments than had ever been made before for a like purpose, conducted chiefly by Mr. Baily and the late Lieutenant Murphy. This is now, in fact, the standard scale of the country; or, at least, the only measure from which the standard scale can be deduced. The manner of conducting the comparisons has already been slightly described; we shall now proceed (from the Report already quoted) to give some account of the difficulties which were found in the way of measurement, and of the results.

This scale is a cylindrical tube of brass 63 inches long, 1·12 inches and ·74 inches in exterior and interior diameter. Three thermometers are immoveably inserted into its length, and the ends are stopped by brass plugs. Two parallel lines (·09 of an inch apart) are drawn in the upper surface; and, commencing 1¼ inches from one end, at the distance of every foot, a palladium pin is inserted in the tube, between those lines; on each of which pins, at proper distances, a fine line is cut to designate the length of a foot. The first foot is similarly divided into inches and tenths; and the middle foot (there being five in all) is bisected. The three middle feet constituted the yard which was used in the comparisons. It was found that any constraint, however slight, affected the expansion and contraction of the bar; even the friction arising from its first supports, which were lined with baize: it was therefore found necessary to support it, when under the microscopes, on friction-rollers: and care was taken that these should always be placed under the same points of the tube. To give an idea of the power of the mode of comparison, it was found, by fourteen experiments agreeing very well with each other, that the middle yard was shortened ·48 of one of the divisions of the micrometer-head (described at the beginning of the article), or ·000024 of an inch, by nothing but removing the plugs from the end of the tube.

Nothing can be known of such a bar as a scientific standard until the rate at which it expands by the action of heat is determined. By a mean of six experiments, taken with the tube at the freezing and boiling temperatures, it was found that every addition of 1° of Fahr. to the temperature lengthened the centre yard by ·000377 of an inch, or 7·6 divisions of the micrometer-head.

The instrument being placed ready for observation, and two scales being put down for comparison, one observer may bring both the micrometers to the ends of one scale, or one observer may be placed at one end, and another at the other. In the latter case, a new cause of error enters, of which it is impossible to give any account, though a remedy may be provided. It is not true that two persons, though using exactly the same instrument, and noting the same phenomenon under the same circumstances, will note it exactly in the same way. When one observer made (as he thought) the coincidence of the intersection of the micrometer-wires with the dot or line at the end of a scale, another, looking into the microscope, would seldom or never agree with the former that the coincidence was exactly made, but would turn the micrometer-head three or four divisions, one way or the other, before he (the second) could be satisfied that the coincidence was perfect. This difference of the manner of observing, arising from the peculiar habits of vision and judgment of the observers themselves, has received the name of the *personal equation*, and its amount, as between any pair of observers, can be ascertained by experiment. If one observer made the coincidences at both ends, it would matter nothing what his manner of observing was, since, however much he might differ from absolute correctness (be that what it may), he would differ by the same amount at both ends, and the length of the scale would not be affected. If, when two observers are employed, they make a given number of comparisons, and then change places and make the same number, the mean of all their observations will be unaffected by their mode of observing, since, if the scale be made too long in the first set, it will be made as much too short in the other, and vice versâ. [EQUATION, PERSONAL.] Some of the personal equation might arise from the curious figures which the dots of the old scales (into which beam-compasses had been inserted) presented when viewed under the microscope. Bird's standard of 1758, for instance, had pear-shaped holes at its extremities, the centres of which no two persons could agree upon.

The following results will give a notion of the degree of accuracy obtained in the workmanship of scales. The Astronomical Society's scale was compared with the imperial standard (Bird's of 1760): the Royal Society's scale of 1742, having two scales in it marked E and Exch.; a scale called Aubert's, the prototype of one which was used in the Indian survey by Lambton; one which had been used by Sir G. Shuckburgh; one belonging to the town of Aberdeen; one belonging to Mr. T. Jones; and four new ones made after the model of the Society's scale, one for the Danish government, one for the Russian government, one retained for himself by Mr. Simms the constructor, and one for Mr. Baily. Calling the middle yard of the Astronomical Society's scale 36 inches, the different scales are as follows, each from the mean of many observations:—

Scale.	Standard portion.	Mean inches of Ast. Soc. scale.
Astron. Soc.	centre yard.	36·000000
Danish	,,	35·999758
Russian	,,	36·000050
Simms's	,,	35·999903
Baily's	,,	35·999949
Aberdeen	,,	35·998615
Jones's	,,	35·909802
Aubert's	0 in.—36 in.	35·998447
Shuckburgh	0 in.—36 in.	36·000185
,, ...	10 in.—46 in.	35·999921
Royal Society	line E	36·001473
,, ...	line Exch.	35·993684
Imperial standard of Bird's of 1760 . . .		35·999624

Temperature is not here alluded to, it being presumed, of course, that the effect of temperature upon the *difference* of two scales is inappreciable: thus the Astronomical Society's standard being ·000376 longer than the imperial standard, and the standard temperature being 62°, the length of the former standard, observed at 62°, and diminished by ·000376 of an inch, will give the true standard of the law.

It is believed, after all, that the imperial standard is about 1-140th of an inch longer than the old standard of the country; but this matters nothing to the scientific part of the question, for all the scales which have been used in trigonometrical surveys have now been diligently compared with the Astronomical Society's scale, and are therefore known, independently of the national standard, as long as the latter scale exists. The only thing to be feared is the loss of this last-mentioned standard; the government might keep it, but cannot be trusted to use it; the Society, which knows how to use it, has no place of perfect security in which to keep it.

We shall not here enter into the various modes used by Sir G. Shuckburgh, and subsequently by Captain Kater, for the determination of the standard of weight. An old standard pound exists in the Exchequer, from which in 1758 a copy was made for the committee of the House of Commons. This last, as we have seen, has been declared the standard, and was never recovered from the ruins of the late House of Commons. The original standard of weight, as prescribed in a statute of 51 Hen. III., called *Assiza Panis et Cervisiæ*, was that an English penny called the sterling, round without clipping, should weigh 32 grains of wheat, well dried and gathered out of the middle of the ear; and that 20 pence should make an ounce, and 12 ounces a pound.*

In 1838 a Treasury Commission was appointed to consider the best mode of replacing the ruined standards of weight and measure. The report of the commission was presented to the government on the 21st of December, 1841. The opinion was expressed therein that the definition contained in the act 5 Geo. IV. cap. 74, by which the standard yard was declared to be a certain brass rod was the best which could possibly be adopted. With regard to the restoration of the standard the commissioners were not prepared to recommend, conformably to the said act, that it should be effected by taking the length which shall bear a certain proportion to the length of the pendulum vibrating seconds of mean time, in the latitude of London, in a vacuum, at the level of the sea. They remarked that since the passing of the act above mentioned, it had been ascertained that several elements of reduction of the pendulum experiments referred to therein, were doubtful or erroneous. Dr. Young had shown that the reduction to the level of the sea was doubtful. Bessel and Baily had proved that the reduction for the weight of the air was erroneous: Baily had pointed out that the specific gravity of the pendulum was erroneously estimated, and that the defects of the agate planes introduced some degree of doubt. Finally, Kater had shown that very sensible errors were introduced in the operation of comparing the length of the pendulum with Shuckburgh's scale used as the representative of the legal standard. On these grounds it appeared evident to the commissioners that the course prescribed by the act would not necessarily reproduce the length of the original yard. They remarked, however, that several measures were in existence which had been accurately compared with the former standard, more especially the Royal Astronomical Society's scale, and the iron bars belonging to the Board of Ordnance, and they asserted that by the aid of these the values of the original standard might be restored without sensible error. They further expressed their firm belief that by employing due care it will always be possible to effect the restoration of a standard by the aid of material copies which have been accurately compared with them, more securely than by experiments having reference to any natural constants. They accordingly offered a series of suggestions, of which the following are the most important:—

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* The latitude of London was rather a vague phrase for legislation which could not let "length" pass without the explanation "lineal extension."

* Here ends the article on Standard Weights and Measures as it originally appeared in the 'Penny Cyclopædia' from the pen of the late Mr. Sheepshanks. The continuation is mainly derived from a paper by Mr. Airy, published in the 'Philosophical Transactions' of the Royal Society for 1857—'Account of the Construction of the New National Standard of Length, and of its principal Copies,' vol. clxvii., pp. 621-702.

1. That so much of the act 5 Geo. IV. c. 74 as provides for the restoration of the standards in the manner therein mentioned, be repealed; and that the standard of length be defined in subsequent enactments of the legislature, either by the whole length of a certain piece of metal or other durable substance, supported in a certain manner, at a certain temperature; or by the distance between two points or lines engraved on the surface of a certain piece of metal or other durable substance, supported in a certain manner, at a certain temperature; but that the standard be in no way defined by reference to any natural basis, such as the length of a degree of meridian on the earth's surface in an assigned latitude, or the length of a pendulum vibrating seconds in a specified place.

5. That four sets of copies (to be denominated the parliamentary copies) of the standards of length and weight be made, in all respects similar to the legal standards of length and weight (which are hereinafter denominated the parliamentary standards), and as nearly as possible equivalent to them; their difference from the parliamentary standards, if appreciable, being carefully ascertained; and that the several parliamentary copies be distinguished by proper marks.

6. That one set of the parliamentary copies be enclosed in a case hermetically sealed and embedded within the masonry of some public building; and that the place in which it is enclosed be pointed out by a conspicuous inscription on the outside; and that this set of copies be not disturbed without the sanction of an act of parliament.

17. That the superintendence of the construction of the new parliamentary standards be intrusted to a committee of scientific men, to be named by her Majesty, subject to the general instructions which follow.

18. That the superintending committee be instructed to combine, in the way which may appear most advantageous, the evidence afforded by the Royal Astronomical Society's scale No. 46, and by the 3 feet bars of the Ordnance Survey; and by the use of these to construct a new standard of length, representing as nearly as possible the same measure as the lost standard.

The government, acting upon this report, appointed a committee of scientific men to superintend the carrying into effect of the operations recommended by the commissioners. The committee thus formed consisted in fact of the commissioners themselves, who were requested by the government to continue their services. The following is a list of the individuals of which it was composed:—The Astronomer Royal, the Marquis of Northampton, the Lord Wrottesley, F. Baily, J. E. D. Bethune, J. G. S. Lefevre, Sir J. W. Lubbock, the Rev. G. Peacock, Rev. R. Sheepshanks, Sir John Herschel, and Professor Miller.

The Earl of Rosse was subsequently appointed a member of the committee. Mr. Baily undertook to execute the operations for restoring the standard of length. The work relating to the standards of weight was undertaken by Professor Miller of Cambridge. [MILLER, WILLIAM HALLOWS, in BIOG. DIV.]

The committee having carefully considered the advantages and disadvantages of line measures, as compared with end measures, decided upon making the standard of length a line measure.

The next point to be considered was the material of which the new standard was to be composed. A series of interesting experiments was made by Mr. Baily, with a view to this object. The committee finally decided upon adopting for the material of the standard of length, an alloy of copper, tin, and zinc, in the following proportions:—

Copper	16
Tin	2½
Zinc	1

Mr. Baily next made a series of valuable experiments on the circumstances which exercise a disturbing influence on the length of a bar. Captain Kater had found that the length of the bar is sensibly affected by small inequalities of the surface on which it rests. It resulted from this circumstance, that the same bar, when compared with other bars at different times, might not indicate the same length. This was fully verified by the experiments of Mr. Baily. It followed as a necessary consequence of this circumstance, that no reliance could be placed on the existing copies of Shuckburgh's scale as representatives of the scientific standard of length, since we possessed no security that we were thereby referring to a consistent system.

Besides Shuckburgh's scale, which was found to be unworthy of confidence, there existed five other standards, which had been carefully compared with the imperial standard. Mr. Baily having obtained temporary possession of four of these, the Royal Society's 3-foot brass scale, the Astronomical Society's tubular scale, and the two 3-foot iron bars of the Ordnance Survey, instituted a series of careful comparisons of their lengths under different conditions. The results of these experiments were by no means satisfactory as regards the degree of reliance to be placed on these bars, as representatives of the imperial standard.

Mr. Baily died in the autumn of 1844. At the request of the committee, Mr. Sheepshanks undertook to continue the operations.

It appeared to the committee that no reliance could be placed either on Shuckburgh's scale, or on any other existing copy of the imperial standard, the experiments of Mr. Baily having shown that the comparisons of those measures could not fail to have been sensibly affected by errors of different kinds. "It was plain therefore that either in the scientific or the legal sense, the restoration of the standard was indeterminate. The formation of a new standard must be an operation *de novo*; the length must be confined within certain limits (wide in the scientific, narrow in the commercial sense), but within these it might have any definite value, and when that definite value was fixed, it must in no way be again referred to the old standards or scales, whether original or intermediary. The principal object now was to ensure constancy and definiteness to the new standard and its copies, and means of reducing without sensible error the comparisons which might be made with them. As far as depended on the standard itself, it was hoped that the construction adopted gave sufficient security. As regarded the means of making comparisons, a far firmer apparatus than had hitherto been used was requisite. As regards the effects of temperature, it was necessary to create an entirely new system of thermometers, founded upon the natural constants, to be determined by appropriate physical experiments; and to use them in new determinations of thermometric expansion."[*]

It was found in the course of the experiments that a change of 0°·01 Fahr. produces a sensible effect in the measure of a bar. It was therefore necessary to employ thermometers which would serve to indicate variations of temperature of no greater magnitude than this. At the time when Mr. Sheepshanks commenced his experiments there were not to be found in England any thermometers of such delicacy. He was consequently induced to undertake the construction of an original system of thermometers adapted to the important object of his labours. He then proceeded to determine the thermometric expansion of a great number of bars of different metals.[†] This object being accomplished, the next step was, by means of the existing standards, to determine the relation of the length of one of the new bars to the lost imperial standard. After many comparisons, he finally decided upon adopting a bar designated by him bronze 28, as a suitable representative of the imperial standard. He remarked, with reference to the circumstances which led him to adopt this resolution, that bronze 28 was as nearly as possible equal in length to the imperial standard, measuring in fact 35·999992 in., that it floated evenly in quicksilver, and that it was nicely divided.

Having now obtained a satisfactory representative of the imperial standard, Mr. Sheepshanks made a great number of comparisons of the length of the new standard with other bars, in order to select from them four Parliamentary copies of the standard, to be disposed of in the way recommended by the committee to the government. He also made careful comparisons of these with a great number of other bars, which were intended for distribution throughout the empire and in foreign countries. It would be out of place here to enter into the details of his arduous and persevering labours in connection with this great national work. It may give the reader some idea of their magnitude when we state, upon the authority of Mr. Airy, that in the course of them he executed about two hundred thousand micrometric measures. He still continued to labour at his task when, in the summer of 1855, symptoms of a serious nature affecting his health began to manifest themselves. On the 28th of July in that year he was engaged on the comparing apparatus, and returned in the evening to his residence at Reading. On the following day he was struck with apoplexy, and died on the 4th of August. We quote the following tribute to his character by Mr. Airy:—

"Thus died—almost in the scene of his labours, and with his thoughts still intent on them—a man whose equal in talent and perseverance, in disinterestedness, in love of justice and truth, I have scarcely known.[‡] He had, however, brought to a satisfactory termination the great division of the standard-work which best suited his taste, having well overcome the last of the difficulties which had presented themselves, and leaving the work in such a state that not a single additional comparison of line-measures was compared. All that was necessary was to collect and arrange the papers, to complete some few means and abstracts which he had been unable to finish, and to draw up such an account as I have attempted here." ('Phil. Trans.,' 1857, p. 684.)

The form adopted for the standard, and for all its copies, is that of a solid square bar, 38 inches long and 1 inch square in transverse section. Near to each end a cylindrical hole is sunk (the distance between the centres of the two holes being 36 inches) to the depth of 0·5 inch. At the bottom of this hole is inserted in a smaller hole a gold plug or pin about 0·1 inch diameter, and upon the surface of this pin there are cut three fine lines at intervals of about 0·01 inch transverse to the axis of the bar, and two lines at nearly the same interval parallel to the axis of the bar. The measure of length is given by the interval between the middle transversal line at one end and the middle transversal line at the other end, the part of each line which is employed being the point midway between the longitudinal lines. The other transversal lines were used in the operations of comparison only for assigning the scales of the micrometers.

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[*] 'Phil. Trans.,' 1857, p. 646.

[†] They were chiefly of gun-metal, as recommended by the committee; but there were also several of cast-iron and steel.

[‡] Mr. Sheepshanks' public services, in connection with the restoration of the national standard of length, were wholly gratuitous.

The committee having carefully examined the numerous bars placed at their disposal by Mr. Sheepshanks, agreed in considering the bars denominated by him bronze 19 and bronze 28, as exact copies of the imperial standard, and they resolved that bronze 19 should henceforward be regarded as the new national standard.

The final report of the committee addressed to the Lords Commissioners of her Majesty's Treasury was signed on the 28th of March, 1854. The following are a few extracts from this important document:

19. "The report of 1841 recommended (article 5) that, besides the legal standard, there should be prepared four copies, to be deposited in places to be afterwards determined.

20. "The expansions of these bars corresponding to a given change of temperature had been sufficiently determined in the course of the experiments; and it was then judged expedient, instead of stating the difference in length of the selected bars at the same temperature, to infer the difference of temperature which would cause all to represent the same length, by the application of which it would be possible to assign the specific temperature at which each bar represents precisely the length of one yard. Thus it was found that the length of one yard as given by the lost imperial standard, is represented with no sensible uncertainty, except in the measures of the imperial standard itself, by the following bars, at the temperatures placed opposite to them.

Bronze 19 or No. 1, at 62°·00 Fahrenheit.
Bronze 20 or No. 2, at 61°·94 Fahrenheit.
Bronze 2 or No. 3, at 62°·10 Fahrenheit.
Bronze 7 or No. 4, at 61°·98 Fahrenheit.
Bronze 10 or No. 5, at 62°·16 Fahrenheit.
Bronze 28 or No. 6, at 62°·00 Fahrenheit.

21. "The degrees of temperature for the use of these standards are defined as proportional to the corresponding apparent increase of volume of quicksilver in the thermometer tube; the degree 32° representing the freezing point of water; and the degree 212° representing the temperature of steam under Laplace's standard atmospheric pressure, or the atmospheric pressure corresponding to the following number of inches in the barometric reading reduced to 32° Fahr.:— $29·9218 + 0·0766 \times$ cosine (2 latitude) $+ 0·00000179 \times$ height in feet above the sea; and the degree 62° denoting the temperature which produces in quicksilver an apparent expansion equal to $\frac{30}{180}$ of the expansion between 32° and 212°; and so in proportion for other degrees.

23. "We propose that the bar No. 1 be adopted by the legislature as the *parliamentary standard of one yard;* that Nos. 2, 3, 4, 5 be adopted as parliamentary copies; and that No. 6 be retained by some officer of the government for the comparison of other bars, or for other scientific purposes in which reference to the standard may seem to be required.

35. "After careful consideration we recommend:—

"That the copy of length standard, No. 2, and the copy of weight standard P.C., No. 1, be deposited in the Royal Mint.

"That the copy of length standard, No. 3, and the copy of weight standard, P.C., No. 2, be transferred to the Royal Society.

"That the copy of length standard, No. 5, and the copy of weight standard, P.C., No. 3, be deposited in the Royal Observatory of Greenwich.

"That the copy of length standard, No. 4, and the copy of weight standard, P.C., No. 4, be immured in the cill of the recess on the east side of the lower waiting hall in the New Palace at Westminster.

40. "After due consideration of this question, referring to the reasons explained in Chapter II., of the report of 1841, December 21, we adhere to the recommendation contained in that chapter, and embodied in Articles 1 and 2 of the same report, that no reference be made to natural elements for the values represented by the standards.

41. "We consider the ascertaining of the earth's dimensions and of the length of the seconds pendulum in terms of the standard length, and of the weight of a certain volume of water in terms of the standard weight, as philosophical determinations of the highest importance, to the prosecution of which we trust that her Majesty's Government will always give their most liberal assistance; but we do not urge them on the government at present as connected with the conservation of standards."

The Lords Commissioners of the Treasury adopted the report of the committee, and a bill was introduced into parliament relative to the new standard weights and measures. This bill received the royal assent on the 30th of July, 1855. It is styled an Act for legalising and preserving the restored standards of weights and measures. In the preamble of the bill allusion is made to the provisions in the act 5 Geo. IV. c. 74, for legalising and ensuring the restoration of the standards. After referring to the destruction of the standards by the fire of the Houses of Parliament, and to the doubts entertained by scientific men respecting the adequacy of the methods provided by the said act for their restoration, it then announces the labours of the committee of weights and measures, describing the construction of the new standards of weights and measures, and their parliamentary copies, and specifies the places in which they have been respectively deposited. It then proceeds thus:—

"And whereas it is expedient to legalise the standards so constructed, and to provide for the preservation thereof: Be it therefore enacted by the Queen's most excellent Majesty, by and with the advice and consent of the lords spiritual and temporal and commons in this present parliament assembled, and by the authority of the same as follows:—

"I. So much of the said act of the fifth year of king George the Fourth, as relates to the restoration of the imperial standard yard, and of the standard troy pound respectively, in case of loss, destruction, defacement, or other injury, shall be repealed.

"II. The straight line or distance between the centres of the two gold plugs or pins in the bronze bar deposited in the office of the Exchequer, as aforesaid, shall be the genuine standard of the measure of length called a yard, and the said straight line or distance between the centres of the said gold plugs or pins in the said bronze bar (the bronze being at the temperature of sixty-two degrees by Fahrenheit's thermometer), shall be and be deemed to be the imperial standard yard.

"VII. If at any time hereafter, the said imperial standard yard and standard pound avoirdupois respectively, or either of them, be lost, or in any manner destroyed, defaced, or otherwise injured, the commissioners of her Majesty's Treasury may cause the same to be restored, by reference to, or adoption of, any of the copies so deposited as aforesaid, or such of them as may remain available for that purpose."

For an account of the restoration of the standard of weight, we must refer the reader to a paper by Professor Miller, printed in the 'Transactions of the Royal Society,' for 1856 ('On the construction of the New Imperial Standard Pound, and its Copies of Platinum;' and 'On the Comparison of the Imperial Standard Pound with the Kilogramme des Archives,' 'Phil. Trans.,' vol. cxlvi., pp. 753-946). We shall merely quote from the new act the following extracts relating to the standard of weight:—

"I. So much of the said act of the fifth year of king George the Fourth, as relates to the restoration of the standard troy pound, in case of loss, destruction, defacement, or other injury, shall be repealed.

"III. The said weight of platinum marked P.S., 1844, 1 lb., deposited in the office of the Exchequer, as aforesaid, shall be the legal and genuine standard measure of weight, and shall be and be denominated the imperial standard pound avoirdupois, and shall be deemed to be the only standard measure of weight from which all other weights and other measures having reference to weights shall be derived, computed, and ascertained, and one equal seven-thousandth part of such pound avoirdupois shall be a grain, and five thousand seven hundred and sixty such grains shall be, and be deemed to be, a pound troy.

"VII. If at any time hereafter the said imperial standard pound avoirdupois be lost, or in any manner destroyed, defaced, or otherwise injured, the commissioners of her Majesty's Treasury may cause the same to be restored by reference to, or adoption of, any of the copies so deposited as aforesaid, or such of them as may remain available for that purpose."

WEIR, or WEAR, is a dam erected across a river, either for the purpose of taking fish, of conveying a stream to a mill, or of maintaining the water at the level required for the navigation of it.

The erection of weirs across public rivers has always been considered a public nuisance. Magna Charta (c. 23) directs that all weirs for the taking of fish should be put down except on the sea-coast. By the 12 Edw. IV. c. 7, and other subsequent acts, weirs were treated as public nuisances, and it was forbidden to erect new weirs, or to enhance, straighten, or enlarge those which had aforetime existed. Hence in a case where a brushwood weir across a river had been converted into a stone one, whereby the fish were prevented from passing except in flood-time, and the plaintiff's fishery was injured, this was considered to be a public nuisance, although two-thirds of the weir had been so converted without interruption for upwards of forty years. And it was laid down that though a twenty years' acquiescence might bind parties whose private rights only were affected, yet that no length of time can legitimate a public nuisance.

The provision of the Roman law as to the maintenance of public rivers (flumina publica) against any impediment to navigation, or against any act by which the course of the water is changed, are contained in the Digest (43 tit. 12, 13).

WEIRS. The constructions, whether of stonework, timber, or earth, by means of which the waters of a river are retained to a given height, or are diverted in any required direction, are known in the arts by the name of *weirs*, or *dams;* and they are principally used for the purposes of creating mill-heads, artificial navigations, or head-waters for irrigations. They may either be placed directly across a stream, or in the line of its flow; and when placed in the latter direction, they may be made to regulate the height of the stream by the level of their crown, in which case the weirs are called *waste weirs*, or tumbling bays, because the excess of the waters, beyond the quantity necessary to keep the surface up to the level of the crown, falls over the weir, and escapes through the byewash, without producing any useful effect.

The height of a weir is, of course, regulated by the depth of the water required to be upheld, and in many cases they are made in such a manner that the upper portion may be raised or lowered at will. In river navigations this variable height is often of great importance on account of the great differences which occur in the volume of the stream; but in millworks the waste weirs are usually made to perform the function of regulators, thus leaving the water line near the shuttle at a constant level. Weirs across rivers are always accompanied by lock-chambers, or by flushing sluices, according to the nature of the traffic, in order to facilitate the passage from the level of the upper to the lower reach of the stream; and whenever lock chambers are formed, it is important that their tail bays should fall again into the main stream at a point beyond the influence of the water falling over the crown of the weir. In forming these structures it is necessary to guard against the syphonic action of the water ponded up in the head bay, which has a great tendency to penetrate the materials composing the weir, and to blow them up, should their specific gravity not be such as to ensure the stability of the structure; and also to guard against the undermining action of the water falling over the crown of the weir. On the former account it is desirable that the height of the head waters should be kept as low as possible, with regard to the convenience of the peculiar service considered; on account of the latter it is desirable that the down side of the weir should present a gradually inclined slope, so as to obviate the effects of the cataract, which would exist if the lower face wall were vertical. In many cases the weirs, which are placed across rivers, are made to present an angle to the course of the stream, in order to offer a greater length, and consequently a smaller depth of water, on the crown; but there can be no absolute rule in this matter, as in so many of the other practical details of hydraulic engineering.

The thickness of water falling over a weir is calculated by the formula $x = 0{\cdot}64 \sqrt[3]{\left(\frac{\text{Q}}{\text{L}}\right)^2}$, in which x = the thickness sought; Q = the discharge per second; and L = the length of the weir. It is, however, important to observe that although the effect of these weirs is to cause an accumulation of waters on their upper sides, the greatest depth is not found immediately upon them, but at a certain distance above them in the line of the stream. The surface of the fluid, in fact, assumes a convex form before arriving at the weir, the curve of which commences at a point on the up-stream dependent upon the velocity of arrival. It is considered that the outline of the curve is a portion of an hyperbola, whose summit is above the weir before the waters begin to fall, and whose asymptote is the line of the natural mean fall of the waters before the establishment of the weir. According to d'Aubuisson and Guilhem, the equation to this curve is $\left(\frac{y+px}{\text{H}}\right)^2 - \frac{px}{\text{H}} = \frac{1}{1+\frac{4\text{H}}{g}\left(\frac{px}{\text{H}}\right)6}$; in which x = the horizontal distance from any point in the curve to the weir; y = the height to which the waters are heaped up at that point above the original level; H = the greatest height to which they are raised; and p = the fall of the river, in this case supposed to have a straight course. As a general rule, the crown of a weir across a stream is kept at about 8 inches, or a foot, below the height calculated for the augmented depth.

Very good models of leading weirs have been executed by Smeaton, on the river Carron; by Telford, on the Weaver; and by Stevenson, on the Ribble and on the Dee. The American engineers have introduced a very economical form of weir, consisting of what is called cribwork of timber filled in with loose rubble; and the Dutch engineers execute with surprising skill weirs or dams of earthwork, bundles of reeds, and fascines. A very ingenious description of moveable weirs is used upon the Seine, in order to close the passage of the subsidiary channels in the dry season; it was invented by M. Poirée, and has been described by him in a pamphlet upon the subject. The waste weirs, and the head weirs of the majority of English mill streams, are rudely constructed earthen banks, which are too often undermined, and left in a very unsatisfactory state of repair: our canal weirs are, however, skilfully formed, as a general rule. Upon the great Indian irrigation canals the most extraordinary works of this description are to be found; and the reader is referred, for a description of them, to General Baird Smith's, 'Indian Irrigation,' and to his 'Irrigation of the Madras Provinces.'

Upon some of our rivers, structures composed of basket-work are placed for the purpose of arresting the progress of fish in their migrations up or down the stream, which are known by the name of fish weirs. These structures do not interfere with the conditions of flow of the rivers, and as their efficiency for the desired end must be regulated by the habits of the fish they are designed to catch, the mode of their construction must be regulated by local conditions.

WELD. [COLOURING MATTERS.]

WELDING is the process of uniting pieces of metal by hammering when hot. It depends on properties chiefly possessed by iron and the allied group of metals; and is illustrated by the details given under CUTLERY; IRON; STEEL; &c.

WELLS. The term Well is, generally speaking, applied to any excavation sunk in the ground, for the purpose of obtaining, or of getting rid of water; the technical distinction between the two kinds of wells being that the former are known by the simple name of *well*, the latter by the names of *dead wells*, or of *absorbing wells*, accordingly as the water escapes by deep seated, or by superficial permeable beds. The distinction between Artesian and common wells has already been referred to under ARTESIAN WELLS; and that between a *shaft* and a *well* consists in the fact that shafts are generally dry, and are intended to give access to galleries, tunnels, or subterranean workings, whereas wells are intended to act as reservoirs of water.

Common wells are made by sinking an excavation through an upper permeable, or partially permeable, stratum, which lies upon an impermeable one, in such a manner as to allow the water falling upon the surface to percolate through, and to accumulate in, the upper stratum. The depth to which it may be necessary to sink a well will then depend on 1, the permeability of the water-bearing stratum; 2, on its area; 3, on its thickness; 4, on the relief of the upholding stratum; and 5, on the existence of other wells, or places of draught upon the source of supply. The diameter of the well will depend upon the rapidity with which the water will enter from the sides, or bottom, to replace the consumption; it being always observed that there are *à priori* advantages in making the well of large dimensions, in order to obviate the effects of the stagnation of the water, which affects small quantities more rapidly than it does larger ones. The construction of the sides, and of the margins of the wells, must depend entirely upon the nature of the ground traversed, and upon its greater or less tendency to cave in.

Generally speaking, the margin of a well intended to supply water for domestic use is executed of watertight masonry, and the well itself is lined with masonry of the same description to some considerable depth, in order to shut out from the well the infiltrations from land-drains, and from surface waters. In England this part of the work is done in brickwork and cement, or in cast iron; abroad it is commonly done in ashlar masonry. Below the level to which these waters may reach, the sides of the wells only require to be lined in such a manner as to resist the tendency of the sides to collapse; and this object may in many cases be effected by what is called *dry steining*, or brickwork laid without mortar. It is customary in modern well-sinking to execute the steining by sinking the ground to the full diameter of the outside of the work to depths of about 6 feet each, and then inserting what is called a *wooden curb*, or a frame circular in plan, of from 3 to 6 inches in thickness, at the level of the floor; upon this curb the steining is then built regularly, as close to the side of the well as possible. The ground is excavated from under the upper curbs, which are maintained in their positions either by the friction upon the side of the steining, or by means of shores, struts, &c. In traversing running sands, or formations containing much water, close tubes must be used; and great precautions are required to prevent such sands from *blowing*, that is to say, from rising in the excavation. In the lower parts of all wells, whatever may be the nature of the material used for lining the sides, means must be provided for the ingress of the water; when iron cylinders are used, or close planking of wood is introduced, a series of holes in the circumference will effect this object. Great care must also be taken that the materials employed be of such nature as not to act upon the quality of the waters; and whilst every precaution must be taken to protect the waters from the light, and from atmospheric impurities, it is desirable that an efficient ventilation should take place in the well. Local considerations of economy must, of course, regulate to a great extent the selection of the materials to be used in steining a well; but theoretically it would be preferable to employ none but the hardest fire bricks and Roman cement, or cast-iron. Copper tubes are sometimes used in Artesian wells; but in ordinary wells the cost of copper pipes of the size required would render the use of that material impossible. Wrought-iron tubes are far too liable to rust, to allow of their being used in wells, without their being galvanised; cast-iron pipes are therefore most generally used.

In such formations as the gravels when they hold much water, it usually is sufficient to sink a well in a vertical direction so far as to maintain a good depth of water at all times of the year, provided there be not many wells drawing their supply from the same bed. It rarely happens that the permeable gravel strata of large towns are able to supply the demand made upon them, and it is therefore almost always the case that after the wells have been gradually deepened, their use is forcedly abandoned in such places: the area of supply is in fact limited; the demands of a large population practically are unbounded. But there is another reason of far more serious importance why the ordinary wells of towns are at the present day being gradually abandoned, in the contamination to which they are exposed from the infiltrations from drains, sewers, cesspools, and dead wells, which eventually introduce so large a proportion of organic matters (in the form of the nitrates) into the waters, as to render them unfit for human consumption. The infiltrations from the sewers, or the leakage from the water pipes of a town distribution may, it is true, provide an unexpected quantity of water in the superficial wells; but the earth traversed by it is so charged with organic matters, under all towns, that the quality of the water must be of the most objectionable nature. In towns situated upon the chalk even it has been found that unless the wells are sunk to a great depth, they are subject to contamination from the causes referred to; and it therefore becomes more than usually important to form an impermeable brick steining round those portions of the wells which are within the range of the effects of surface waters.

The gravel, or sand beds, hitherto considered, are penetrated by water in the whole of their thickness able to yield a supply; and the chalk marl, the green sand, the new red sandstone in some of its beds, present the same hydroscopic conditions. But such formations as the upper chalk, the oolites, the slate rocks, &c., do not allow the water to pervade the whole mass; on the contrary, the water only passes through them freely upon their great planes of stratification, or by following the joints of cleavage, or the vertical fissures which so commonly occur in those rocks. If then, wells sunk in the former class of materials should not contain much water (always assuming them to be sunk of the ordinary dimensions, that is to say of about 4 feet clear internal diameter), there is little probability of obtaining an increased supply by domeing out the bottom of the well, or by driving headings or lateral adits. In the latter class of materials, however, it frequently happens that very beneficial results are obtained by thus increasing the contributing area; for it is by no means rare to encounter springs of considerable volume by thus opening up successively the edges of the divisional planes. It is advisable in forming headings, in the strata referred to, to drive them at a slight inclination horizontally to the axis of upheaval of the strata, and vertically to follow their dip, making the height of the heading as great as possible, in order to lay bare the edges of a great number of the beds.

The water obtained from superficial wells is raised to the surface by some one or other of the ordinary machines. Where the consumption is small and the depth inconsiderable, the bucket and windlass will be found generally speaking to be sufficient; where the consumption is large, pumps must be used; common suction pumps will suffice when the lift does not exceed 28 feet; beyond that depth force pumps must be used, and they may be driven by hand, by wind, animal, or steam-power, as may be most advisable. All wells are improved by frequent and hard pumping; for not only does the water they contain undergo a species of unsatisfactory chemical action whilst standing in them, but it is also found that by relieving the pressure upon the edges of the water-bearing strata the water passages become increased.

Dead wells and absorbing wells depend for their action upon the hydrostatical law that water will, when left to itself, attain a uniform level over the whole of the surface. If then a column of water be made to stand upon a water-bearing stratum, the level of the former will subside to that of the normal water-line in the latter; and the excess of the column will be dispersed throughout the stratum. Advantage was formerly taken of this law, in such towns as Southampton, to get rid of the liquid matters of cesspools by sinking them into the permeable water stratum of the district, and leaving the bottom of the excavation open; the liquid matters thus diffused themselves throughout the superficial water-bearing stratum to the ultimate destruction of the wells fed by the latter. Of late years an attempt has also been made at Paris to get rid of the foul waters of the Voirie of that town, by sinking a boring of large diameter to the permeable strata between the chalk and the upper tertiary beds of that locality; but not only has it been found that serious injury was thus done to the neighbouring wells, but that the bore holes very soon became choked up. The fact is that dead wells and absorbing wells are public nuisances of a very serious nature, and their formation ought to be rigorously forbidden and carefully prevented. Unfortunately there is no legislation on any part of the natural conditions of flow of underground waters; nor do any legal means exist by which a landed proprietor could be prevented from contaminating the wells of a large district around him.

(See Swindell, *On Well Boring and Sinking;* Degoussée, *Guide du Sondeur;* Burat, *La Géologie appliquée aux Arts.*)

WELSH LANGUAGE AND LITERATURE.—Language. The Welsh language is that which is now spoken, and has been so far back as historical records extend, in the principality of Wales. The name of "Welsh" was first given to the people who speak it by the Anglo-Saxons, and the same term or a similar one seems to have been used in many of the Germanic and even of the Slavonic languages to denote the Italians, or other nations whose languages resembled the Latin. "Welschland" was the name for Italy in German of the middle ages, and is not yet entirely superseded in the language of the common people; the name of that country in Polish is "Wlochy," and the appellations of the Walloons and the Wallachians appear to be derived from the same root. Singularly enough, the word has a strong correspondence with the appellation given by the Romans themselves to the kindred nation of Gaul, who, as Cæsar tells us, called themselves Celts ("qui ipsorum linguâ Celtæ, nostrâ Galli appellantur"). Wallia and Gallia differ only by a letter, and Gallic and Gaelic have as close a resemblance.

The name which the Welsh give to themselves is "Cymry," and to their language "Cymreig," the obvious resemblance of the sound of which to "Cimbri" has led many to suppose them identical with the Cimbri of Roman history. The meaning now assigned to the word "Cymry" is "primitive," but this meaning does not seem to have occurred to any Welsh scholar before the Rev. John Walters, who first published it about the middle of the 18th century. The Welsh is one of a family of languages generally denominated the Celtic languages, and described as six in number, which were all spoken in the 18th century, and five of which are still spoken in the 19th, four of them within the British islands. These are 1, the Irish, which prevails in different parts of Ireland: 2, the Gaelic of the Highlands of Scotland: 3, the Manks, which is decaying and appears to be dying in the Isle of Man: 4, the Welsh, or language of Wales: 5, the Cornish, formerly spoken in Cornwall, but now extinct, and 6, the Armoric or "Bas-Breton," prevalent in some departments in the ancient province of Lower Brittany in France. All of these languages which still survive have occupied for centuries a subordinate position to some other language, the first five to English and the sixth to French. They have thus been precluded from the advantage of being spoken by the higher classes of society, and have in many cases for want of a standard of phraseology and pronunciation separated into dialects, some of which in process of time have been considered as distinct languages.

The degree of affinity between the different Celtic languages is a point of considerable interest. A controversy was carried on in 1839 on the question whether the Gaelic and Welsh, two languages in common use in different parts of our own island, are, or are not connected. The prevalent opinion for a long time had been that they were dialects bearing a close resemblance to each other: Schlözer and Adelung hinted suspicions of the correctness of this view; and Sir William Betham, in his 'Gael and Cymri,' published in 1834, asserted that they were wholly dissimilar. Professor Forbes, the learned Orientalist, whose native tongue is Gaelic, maintained the same views as Sir William, in an animated correspondence on the subject, which appeared in the 'Gentleman's Magazine' for 1836 and 1838. The main fact which he announced, that the most intimate knowledge of the Gaelic language would not enable a person to master a single verse of the Bible in Welsh, was certainly new to the world in general, and would never have been suspected from the tone in which most Celtic scholars were accustomed to speak of the affinity of the languages; but the inference which he drew from it, of a total want of connection between the two, was satisfactorily refuted by other facts. The Rev. Richard Garnett, of the British Museum, who was induced to search into the question by the statements of Professor Forbes, reported in the 'Gentleman's Magazine' for May, 1839, that on examining the monosyllabic words in the introductory portion of Neilson's Irish Grammar, about 270 in all, he found of

Words perfectly identical with corresponding Welsh terms in sense and origin	140
Clearly cognate	40
Derived from the Latin, Saxon, &c., repetitions and compound terms	40
Peculiar to the Gaelic	50

"In the Grammar," he added, "prefixed to Armstrong's Gaelic Dictionary there is a list of about two hundred verbs in common use. Seventy, or more than one-third of the whole, are unequivocally cognate with Welsh and Armoric, and twenty more probably so." "In 'Stewart's Gaelic Grammar' we have a list of twenty-four simple prepositions (omitting mere varieties of form), and about forty improper, or compound. Of the former, fourteen are Welsh, and three Cornish; and of the latter, eighteen, or nearly one-half, radically Welsh." Mr. Garnett remarked with justice, that "the amount of resemblance is hardly so great between Icelandic and German," and these are unquestionably kindred languages.

The Celtic languages must, therefore, be divided into two great branches, one of which comprises the Irish, the Gaelic, and the Manks, and the other, the Welsh, the Cornish, and the Armorican. The Irish and Gaelic have a very close resemblance, and in fact, their separation from each other appears to have been remarkably recent. The book that is generally cited as the earliest printed in Gaelic, is a translation of John Knox's 'Liturgy, or Forms of Prayer,' by John Carsewell, Bishop of the Isles, which was issued at Edinburgh in 1567, four years before anything whatever in Irish was printed in Ireland. The Rev. Thomas Maclauchlan, a Gaelic scholar, in his 'Celtic Gleanings,' a course of lectures delivered at Edinburgh in 1857, informs us that "the dialect of Gaelic used by Carsewell is that commonly known as the Irish, but which was common to the writers of both countries. It is manifest," he adds, "that Carsewell did not acquire this dialect in Ireland, for we have no reason to believe that he ever visited Ireland, and his saying that he knew nothing of the dialect but what was current in the country, shows that the possession of this dialect was not in itself an evidence of very high scholarship, but was somewhat common among the people." The close resemblance of Irish and Gaelic for some time after is shown by the circumstance that about 1690, three thousand copies of Bishop Bedell's Irish version of the Bible were printed for the benefit of the Scottish Highlanders, and Mr. Maclauchlan states, that a gentleman who was living about 1807, remembered hearing the Irish Bible used in the services at the parish church of Kirkhill, near Inverness. It was not till about 1760, soon after the appearance of Macpherson's first 'Specimens of Erse poetry,' that the Society for Propagating Christian Knowledge in Scotland, resolved on encouraging a translation of the Scriptures into Scottish Gaelic, and it was not till 1801, that a complete version existed in print. It would appear, therefore, that while in the reign of Queen Elizabeth, the Lowlands of Scotland spoke a language distinct from English as evidenced in the printed works of Knox, the Highlands spoke a language identical with Irish, as evidenced by the translation of Knox's Liturgy, and that while the language of the Lowlands has gradually assimilated to that of England, the language of the Highlands has gradually separated from that of Ireland. A similar process of disintegration appears to be still going on with the Irish language in Ireland itself—a separate version of the New Testament in the dialect of Munster was issued in 1858, and it is not improbable, therefore, that in the 20th century, there may be a larger number of Celtic languages stated to be in existence than in the 19th. The dialects of Irish vary so much, that it is said that Irishmen from different provinces who are acquainted even imperfectly with English, often make use of English in conversation with each other. An Irish clergyman, who had been a missionary to Shang Haé, informed us that he had been a witness to the use of English as the most convenient medium of intercourse by the natives of different provinces in Ireland, and the natives of different provinces in China. Campion, an English writer of the year 1571, says, that "the true Irish indeede differeth so much from that they commonly speake, that scarce one among five-score can either write, read, or understand it." The Gaelic is now itself divided into two dialects, which seem to have a tendency to diverge more and more. Forms of speech which are frequent in the version of the Scriptures printed in 1801, are not found in the curious collection of Gaelic stories taken down from the lips of Highland narrators, and published by Mr. Campbell of Islay in 1861, one of the most careful records of oral language in existence. The so-called Manks language is a kind of corrupted Gaelic, more different to the eye than the ear, from being written in a less artificial system of spelling. The system of "orthography" of Irish and Gaelic is so excessively complex and difficult, that those who speak them are often unable to read them even when they have learned to read English.

The three forms of the Gaelic branch of the Celtic family of languages are thus intelligible with a little trouble to any person who is a thorough master of one; but this is not the case with the three forms of the other branch. The affinity between Welsh and Bas-Breton is much less than has been sometimes asserted. The best evidence on this point is that of the Rev. Thomas Price, a distinguished Welsh scholar, who made a tour through Brittany in the summer of 1829. "I may," he says ('Cambrian Quarterly Magazine,' vol. ii. p. 197), "be asked a question which I should myself have proposed to another upon a similar occasion, had I never visited Brittany, and that is, if the Welsh and Breton languages bear so near a resemblance to each other as is generally understood, where was the necessity of having recourse to the French as a medium of communication? Why not converse with the Bretons in the Welsh at once? To this I answer that, notwithstanding the many assertions which have been made respecting the natives of Wales and Brittany being mutually intelligible through the medium of their respective languages, I do not hesitate to say that the thing is utterly impossible; single words in either language will frequently be found to have corresponding terms of a similar sound in the other, and occasionally a short sentence deliberately pronounced may be partially intelligible, but as to holding a conversation, that is totally out of the question."

One of the earliest and most valuable books of research and information on the Celtic languages in general is the 'Archæologia Britannica, giving some account additional to what has been hitherto published of the languages, histories, and customs of the original inhabitants of Great Britain, from collections and observations in travels through Wales, Cornwall, Bas-Bretagne, Ireland, and Scotland, by Edward Lhuyd, M.A., of Jesus College, Keeper of the Ashmolean Museum at Oxford.' The first volume, a closely printed folio on 'Glossography' appeared in 1707, and was never followed by a second, the continuation of the work being prevented by the death of the author in 1709. Lhuyd had travelled in all the Celtic countries to collect materials, and was only driven from Brittany by the outbreak of Marlborough's war. He unfortunately adopted a peculiar system of orthography for the Welsh, and took a singular whim of displaying his knowledge of Irish and Cornish, by writing prefaces in Irish and Cornish to parts of his book; the first of which is censured by Irish scholars as full of solecisms, and the second was a 'sealed book,' till portions of it were lately translated into English by Mr. Edwin Norris. But his work comprises a valuable comparative collection of vocabularies, and a large body of miscellaneous information on the manuscript literature of the Celtic languages, similar to the information on the northern languages which was brought together by his friend Dr. Hickes in 1705, in the celebrated 'Linguarum Septentrionalium Thesaurus.' Lhuyd left behind him a large collection of manuscript materials for the continuation of his work, which have unfortunately perished—by three separate accidental fires in London and Wales. The next student of Celtic on an equally extensive scale appears to have been the famous and infamous Eugene Aram, who refers to the subject in an autobiographical letter written in 1759, while he was in confinement in York Castle, not long before his trial and execution. "I investigated the Celtic," says Aram, "as far as possible in all its dialects; begun collections, and made comparisons between that, the English, the Latin, the Greek, and even the Hebrew. I had made notes and compared above three thousand of these together, and found such a surprising affinity, even beyond my expectation or conception, that I was determined to proceed through the whole of all these languages and form a comparative lexicon, which I hoped would account for numberless vocables in use with us, the Latins, and Greeks, before concealed and unobserved. This, or something like it, was the design of a clergyman of great erudition in Scotland, but it must prove abortive, for he died before he executed it, and most of my books and papers are now scattered and lost." This laurel was not destined for a British head. Nearly a hundred years later, in 1853, appeared at Leipsic the most important contribution yet made to Celtic philology, the 'Grammatica Celtica' of Professor Johann Caspar Zeuss of Bamberg, who had devoted thirteen years to the necessary preliminary studies. The book, which extends to two volumes, comprising more than eleven hundred pages, embraces a grammar of the Celtic languages in a mass, the Irish, Welsh, Cornish, Armorican, and ancient Gaulish, constructed on an unusual plan. The author takes the parts of speech separately, and the languages one after the other, treating, for instance, the article in Irish, in Welsh, in Cornish, &c., before he proceeds to examine the substantive in any one of those languages. As in some other German works on philology, the method of treatment is laborious and unattractive, wanting in generalisation, and calculated to repel all but the determined student. The author adopted the medium of Latin as the general language of the learned, but his Latin is unfortunately the reverse of elegant. The value of the work, which is great, consists in the minute and careful scrutiny to which Zeuss has subjected the manuscript materials for a knowledge of the early state of the Celtic languages, which are scattered in the libraries of England and the continent, and which he for the first time brought together. These materials mostly consist of 'Glosses,' or translations of single words or passages in the margins, or between the lines of old Latin copies of the classics. Specimens of interlineary Welsh of this kind are to be found in a manuscript of Eutychius and Ovid in the Bodleian Library at Oxford, of the conclusion of the 8th or commencement of the 9th century, while the 'Black Book of Caernarvon,' and the 'Red Book of Hergest,' the oldest manuscripts of unbroken Welsh, are ascribed by the best judges to the 12th and the 14th centuries, and are thus later in date by no less than four and six hundred years. A steady light was also thrown by Zeuss on the ancient Irish from study of the 'Glosses' in manuscript, which lay unnoticed in the libraries of Germany and Italy; in some cases, as in the library of St. Gall in Switzerland, founded by the Irish monks who converted the Swiss to Christianity, buried and forgotten for a thousand years. The suggestion which he threw out that a minute examination of the manuscripts in English and Irish libraries might probably lead to the discovery of further stores of the same kind has already borne its fruits in the discoveries made by Stokes at Dublin, and Bradshaw at Cambridge, and in all probability much still remains to be dug out. Zeuss himself was unfortunately lost to science by his premature death in 1856, at the age of fifty. In an interesting biographical sketch of him by his learned countryman, Dr. Siegfried, now of Dublin, in the 'Ulster Journal of Archæology,' for 1859, his illness is ascribed to over study.

A great and striking merit of Zeuss's laborious work, and one which makes its publication an epoch in Celtic studies is, that it presents a total contrast in its tone and spirit to that which had too long prevailed in this branch of investigation. The students who follow the track opened in the 'Grammatica Celtica' have no pleasant path before them—it leads amid "Glosses," and other such literature as only the severest philologists can tolerate and none can relish—but their footing is on firm dry ground. Zeuss is not indeed averse to speculation any more than his German colleagues in general, one of his views being that Irish and Welsh were identical not long before the invasion of Cæsar, as Irish and Gaelic were identical a few hundred years ago. But there is a wide difference between such views as these, open to discussion as they are, and the wild hallucinations to which Celtic scholars have been too often subject. Pezron, the Breton investigator, maintained in 1703, in perfect good faith, that Welsh and Breton, which he considered the same language, had been "the language of the Titans, that is, the language of Saturn, Jupiter, and the other principal gods of heathen antiquity." The Rev. Joseph Harris, a respectable Baptist minister of Swansea, editor of the 'Seren Gomer,' observed in 1814, very gravely, that "it is supposed by some, and no one can disprove it, that Welsh was the language spoken by Adam and Eve in Paradise; and if so, what can be more natural than to suppose that it will be the language of the celestial Paradise where all the nations of the earth shall be of one tongue." Unluckily for the force of his observation, not only has the honour of being the language of Paradise been positively claimed for other languages—for Basque by several authors, for Dutch by Goropius Becanus, for Gaelic by Mr. Maclean, author of a 'History of the Celtic Language,' in 1840—but there is a Welsh tradition, unknown to Mr. Harris, which expressly states that Welsh was not the language of Paradise, but the first language spoken out of it. The Rev. John Williams ab Ithel, editor of the 'Cambrian Journal' for the Cambrian Institute, in his preface to an ancient grammar of Edeyrn, which he edited in 1856 for the Welsh Manuscript Society, speaks in a tone of assent of the assertion that there are only three languages of divine origin, that of Adam, that of Moses, and the Welsh; and also of an assertion grounded on bardic tradition respecting the word by which the world was created, and its embodiment in the first letter of the ancient Welsh alphabet. Passages like these, which are but too common in the works of some Celtic scholars, have had the effect of disgusting many with the study of Celtic antiquities.

Some of the more important conclusions to which Zeuss's researches conduct, are embodied by Mr. Edwin Norris, of the Foreign Office, in the valuable observations on the Cornish language, appended to his edition of the remains of the 'Ancient Cornish Drama,' printed at the University Press at Oxford in 1859. "The superior antiquity of the Irish over the British language is now," says Mr. Norris, "scarcely doubted; it is seen as well in their grammatical as in their glossarial relations. The declension of the Irish noun is even yet in existence, and it is shown with much probability to have been closely allied to that of the oldest Indo-European forms at an early period; of the British, the only remnant left is a Cornish genitive, and a scarcely discernible trace in Welsh." He then produces several instances in which, as in *teagh* and *ti*, Irish and Welsh for "a house," and *nochd* and *nos*, Irish and Welsh for "night," letters are dropped in Welsh that remain in Irish, and argues for the greater antiquity of the fuller form. "It may look like the partiality of an editor," he continues, "to ascribe a greater antiquity to Cornish than to Welsh, in the face of the universally adverse opinion, but the writer confesses that he is inclined to consider the Cornish the older of the two;" and he gives his grounds for so doing, principally founded on the fact that it is shown by the glosses produced by Zeuss, that "in the 8th century Welsh had Cornish forms and words which were lost or altered in the 12th." From these premises Mr. Norris infers that "Cornish is the representative of a language once current over South Britain at least." If these views be correct, the Welsh will lose their claim to the honour they have so long retained of being considered the representatives of the "Ancient Britons."

A good comparative dictionary of the Celtic languages would be an acquisition to philology, and is much required. The Rev. Robert Williams, of Llangadwaladr, author of the 'Lives of Eminent Welshmen,' announced in 1860 that he had completed a labour of the kind, the publication of which would be commenced as soon as a sufficient number of subscribers could be obtained. One of the publications of Prince Louis Lucien Bonaparte supplies material for a comparison of the different dialects not otherwise attainable. It is entitled 'The Celtic Hexapla' (London, 1858, 4to), and comprises the Song of Solomon in eight languages, which are all presented to view at the opening of any page—French and English, Irish and Welsh, Gaelic and Manx, Breton of the ordinary form, and Breton of the dialect of Vannes. The two latter translations were first printed in this volume; the others are taken from the authorised versions.

The degree of prevalence of the ancient Celtic element in Europe,—the area over which the various dialects were spoken, and the remains of them which may be still traced out,—is a subject upon which much has been written, but which still awaits its Zeuss. It is however an antiquarian subject alone; it is certain that no Celtic language is now spoken on the continent beyond the limits of Brittany. The Basque of the Pyrenees, so often asserted to belong to the Celtic family, is as distinct, both in words and construction, as can well be imagined. The notion of Dr. Owen Pughe that the Wendish of Lusatia was a language akin to Welsh, is as wide of the mark as the strange notion which found its way by a series of blunders into Adelung's 'Mithridates,' that a Celtic dialect was spoken at Maldon in Essex. The small value of Dr. Owen's statements on such a subject is shown by his declaration in the preface to the edition of Llywarch Hen, published in 1792, that he had "a collection of evidence sufficient to convince as great sceptics as any that will see this" that "the Nadowesses, a people west of the Mississippi in America, known to the Indian traders by the name of the civilised Indians and the Welsh Indians, do now actually speak the Welsh language." "These people," he confidently added, "are the descendants of the emigration under the conduct of Madog ab Owain Gwynedd in the year 1170." The remains of the extinct Celtic languages of the continent are singularly scanty. A few scattered words are all that is preserved of the speech of ancient Gaul—the language that prevailed in France at the time that Cicero wrote in Italy. These words bear so close a resemblance to those of the same meaning in Welsh, as to justify the assumption that there was little distinction between the dialects of France and England at the earliest dawn of history. Whether we ought to believe that the "Celts" who are mentioned by different writers of antiquity in different parts of Europe were all closely connected with one another, or all even rightly named, is a perplexing question. The most reliable evidence now attainable on the subject appears to be that of the names of places, and these must be very cautiously sifted. Dr. R. G. Latham reminds philologists that there is no connection beyond a mere resemblance in name between Gallicia in Spain and Galicia in Poland. A large collection of materials of this kind has been amassed by Dieffenbach in his 'Celtica,' and a work on the subject by Contzen, 'Die Wanderung der Kelten,' which received a prize from the Academy of Munich in 1856, has (in 1861) just issued from the press.

The question of the affinity of the Celtic languages to the other languages of the world is one that has given rise to considerable debate since the epoch that was made in comparative philology by the introduction of the study of Sanskrit, about the commencement of the 19th century. In preceding centuries Welsh had been often compared with Hebrew. "It is commonly observed," says Llewellyn in his 'Historical and Critical Remarks on the British Tongue,' "that the British and the Hebrew are similar languages," on the ground of their being alike in many peculiarities of construction, especially in permutation or the change incident to several letters in the beginning of words, and also in the paucity and confusion of tenses in the conjugation of verbs, and in the binding together in one word of some prepositions and pronouns. This degree of resemblance is certainly not sufficient to place the Welsh and the other Celtic languages in the Semitic family, but in these respects it does resemble the Hebrew and differ from the Greek and Latin, which form a portion of the Indo-European family to which it is now adjudged to belong. The Indo-European family, or rather tribe, is now so extended that it comprises many languages formerly regarded as entirely disjoined, such as Greek and Persian, Russian and English,—while the Semitic only comprises a very small circle of languages bearing a close resemblance to each other—a circle, in fact, no larger than that of the Celtic family alone.

The history of the controversy is an instructive one. For the first thirty years of the 19th century the Celtic languages were supposed, to quote the words of the Rev. Richard Garnett, "to form a class apart, and to have no connection whatever with the great Indo-European stock. This was strongly asserted by Colonel Vans Kennedy, and also maintained, though in more guarded terms, by Bopp, Pott, and Schlegel. The researches of Dr. Prichard in his 'Eastern Origin of the Celtic Nations,' and of Professor Pictet of Geneva, in his truly able work, 'Sur l'Affinité des langues Celtiques avec le Sanscrit,' may be considered as having settled the question the other way. The demonstration of Pictet is so complete, that the German scholars who had previously denied the connection, now fully admit it, and several of them have written elaborate treatises, showing more affinities between Celtic and Sanscrit than perhaps really exist." The work of Dr. Prichard, himself a Welshman, is entitled 'The Eastern Origin of the Celtic Nations proved by a comparison of their dialects with the Sanskrit, Greek, Latin, and Teutonic Languages.' The first edition appeared in 1831; a second, with extensive and important additions by Dr. R. G. Latham, in 1857. On the subject of the Celtic languages in the British Islands, there are some valuable and really instructive papers by the Rev. R. Garnett, in the 'Quarterly Review,' and the 'Transactions of the Philological Society,' which are collected in the posthumous volume of his 'Philological Essays,' edited in 1859 by his son.

The Welsh language is one of the oldest in Europe: the Irish and Welsh are in fact among spoken languages the most ancient of which any written monuments are preserved, unless we regard the modern as identical with the ancient Greek. The Welsh has poems now in existence, the origin of which is believed by the best critics to date back to the 6th century, to a period little after the time when the Romans left the country, in which of course, while they held it, the dominant language was Latin. It is true that Zeuss has shown that the language of these poems, when originally composed, must have differed in a considerable degree from that of the form in which they are preserved to us, and that one of the most learned Welshmen of a century ago, the Rev. Evan Evans, says in his 'Specimens of the Bards,' published in 1763, that he had shown the most genuine remains of Taliesin to the best Welsh antiquaries and scholars then living, and that "they all confessed they did not understand one half of any of his pieces." It is true also that Price, in his 'Hanes Cymru,' a book intended for ordinary readers, found it necessary to give a modern Welsh version of an ancient Welsh poem, which he quoted from Gwalchmai, a bard of the 12th century, who is said to have accompanied Cœur de Lion to the Crusades. Still from about the Norman conquest downwards, there exists a mass of literary matter in a language which is readily intelligible to those who are acquainted with the modern Welsh after a slight degree of study. A similar observation is perhaps applicable to no other living European language except the Icelandic. The language of the Saxon contemporaries of Taliesin has been a dead language for centuries, and even in the time of Gwalchmai the present English was as yet unborn.

The Welsh has long been an object of study to those who speak it. "There are," says Owen Pughe ('Archæologia,' xiv. 220), "about thirty different old treatises on Welsh grammar and prosody preserved. Of these, one is particularly deserving of notice as a curious relic: it was composed by Geraint about 880, revised by Einion about 1200, and again by Edeyrn about the year 1270, and regularly privileged by the different sovereigns who then exercised authority in Wales." This work was first printed by the Welsh Manuscript Society in 1856, under the editorship of the Rev. John Williams ab Ithel. A portion of a grammar which appeared in 1567, from the pen of Griffith Roberts, and of which mention will be made hereafter as remarkable on other accounts, is remarkable also as containing some proposals on the subject of Welsh orthography of an ingenious character, which were not however adopted. Two Latin grammars of the language followed, the 'Cambrobrytanicæ Linguæ Rudimenta' of Dr. David Rhys, in 1592, and the 'Antiquæ Linguæ Britannicæ nunc communiter dictæ Cambro-Britannicæ Rudimenta' of Dr. John Davies, in 1621, both of them much esteemed. There are now several grammars of the Welsh language in English, of which that by the Rev. Thomas Rowland, the second edition of which was published in 1857, may be recommended as the most satisfactory. Dictionaries are less numerous. Dr. John Davies, the author of the grammar, published in London in 1632 a Welsh and Latin dictionary, 'Antiquæ Linguæ Britannicæ Dictionarium Duplex,' which continued in repute for a century and a half, till superseded by that of Dr. Owen Pughe. This work, 'Geiriadur Cymraeg a Saesoneg, a Welsh and English Dictionary,' with a grammar prefixed, published in two closely-printed octavo volumes in 1793, and again in 1829, is still the only Welsh dictionary on a sufficiently extensive scale, and is a work of great labour and merit, but it is open to serious objections. The number of words it contains is nearly 100,000; but many of these are compounds, formed on regular principles, which only serve to swell the book, and many of them are only words which ought to exist in Welsh, according to the lexicographer's opinion, rather than words which actually exist in it. A third edition is now (1861) in course of publication, under the editorship of R. J. Pryse, who promises that the work shall contain "scores of thousands" of words not in the previous editions. As Owen's comprises Welsh and English only, not English and Welsh, the want of the latter was formerly supplied by the excellent English-Welsh dictionary of the Rev. John Walters, of which a new and improved edition was published about 1825. The 'English and Welsh Dictionary' by Daniel Silvan Evans, in two thick volumes (Denbigh, 1852–1858), is however still superior to that of Walters. There are a compendious grammar and dictionary by Mr. Spurrell of Carmarthen, both of which will be found useful. Some information on the Welsh dialects is given in the 'Essay on the Ancient and Present State of the Welsh Language,' by Mr. John Hughes, published about 1820. There are differences in pronunciation and idiom sufficiently marked to render it difficult for persons from remote districts to converse with each other; and North Wales is more pure and correct in its language than South Wales.

The system of spelling in Welsh corresponds with and represents the pronunciation, and in that respect it has a marked superiority not only over its kindred Celtic languages, the Irish and Gaelic, but, as we daily feel to our cost, over the English. There are at the same time some peculiarities in Welsh spelling, the motive of which is not very plain, and the effect of which is often ludicrous. The sound which is generally represented by the letter *v* is in Welsh represented by *f*, even in proper names, so that pronouncing Calvin and Virgil not unlike ourselves, a Welshman writes "Calfin" and "Firgil." The sound represented in the English alphabet by *f* is represented in Welsh by *ff*; and thus Fox and Franklin must be written Ffox and Ffranklin, as, if spelt in the ordinary manner, a Welsh reader might pronounce them Vox and Vranklin. Some efforts have been made by Owen Pughe and others to introduce the missing *v* into the Welsh alphabet; and it is usual for English writers to follow his system in spelling Welsh names—to write Merthyr-Tydvil, for instance, instead of Merthyr-Tydfil. But the advantage of uniformity is so great, that though the present system scarcely dates further back than the 16th century, and though there are several eccentricities like that with the *v*, resistance to innovation has hitherto triumphed.

It has been said, that in English the grammar is excellent and the dictionary is execrable. The grammar of English is, in fact, distinguished by its great comparative freedom from needless complexities, while its list of words comprises thousands that a careful writer will carefully avoid. In Welsh, almost the converse is the case. For useless intricacy its grammar has a bad pre-eminence. It is pervaded from first to last by a certain law of "permutations," the nature of which will best be understood by an instance. The word for "father" in Welsh is *tad*; the word for "my" is *fy*: but to say *Fy tad* for "my father" would be an unpardonable solecism. After *fy*, every word beginning with a *t* must change the *t* to *nh*, and the correct phrase is therefore *fy nhad*. The word for "thy" is *dy*; but after this a different change is required: "thy father" is *dy dad*. The word *ei* in Welsh means "his" or "her," but according to the sense requires a different mutation to follow: "his father" is expressed by *ei dad*, and "her father" by *ei thad*. Some of the letters, as *t*, have three of these mutations to undergo, some only two, some only one, and some none at all. There is a multitude of intricate rules to determine in what circumstances the different mutations are to be used, and at the same time the existence of letters which undergo no mutations whatever, and the words beginning with which are just as elegant and forcible without them, proves to demonstration the utter uselessness of the whole. In the other Celtic languages there is a similar system, but not carried quite so far as in the Welsh. The principle has been generally considered to be peculiar to that family of languages in Europe; but Prince Louis Lucien Bonaparte, in his extensive researches among the obscurer tongues, has discovered slight traces of mutation in some of the dialects of Sardinia. In the complexity caused by an intricate system of declensions and conjugations there is generally some compensation obtained in a superior precision and force; but there is nothing of the kind in mutation. Its origin was long a subject of debate. In some compounds of words it was plain that attention to euphony had given rise to it. The opposite to "possible," in English, is "impossible": both words are taken from the Latin, and the "in" privative, as it is called, is altered to "im" in this and other cases before the letter *p*, to avoid unpleasantness of sound. The Welsh have also borrowed the word *posibl* from the Latin, and for "impossible" they say *anmhosibl*. The Welsh particle answering to our "un" is an; the collision of *n* and *p* was also to be avoided; but instead of altering the last letter of the *an*, they altered the first letter of *posibl*. It has lately been pointed out by Zeuss and his school, that in other cases where *p* is altered to *mh*, it was in the old forms of the language preceded by an *n* which no longer exists. Hence it may be inferred that the whole system of mutations was originally founded on the euphonic principle. While the effect remains, however, the reason for it has disappeared in the actual state of the language. The rules for mutations are at the present day mere arbitrary rules, the motive for which is as unknown to those who practise them as the reason for spelling "wright" with *w* and *gh* is unknown to the schoolboy who is being taught to spell. After all these sacrifices to harmony, the Welsh has never been considered harmonious by those of whom it was not the mother-tongue, though a writer in the 'Cambrian Register' for 1[illegible], affirms that "strangers to both languages frequently mistake the Welsh for Italian."

The principal beauty of Welsh as a language consists in the facility which it possesses of forming derivatives and compounds, and the completeness with which that power has been exercised, making full and ingenious use of every root, and thus avoiding that useless borrowing of terms from other languages which has been carried to such an absurd extent in English. Many foreign words have indeed been introduced into Welsh, but they have been so assimilated to those of native origin as often not to be easily detected. The whole language seems of a piece. But there is this advantage in a language in which the grammar is superior to the dictionary: that by a skilful choice of words, by limiting himself, like Metastasio, to a certain select vocabulary, an author may exclude from his writings all but the beauties of the language; while in the opposite case, the defects—as in Welsh, the rules for mutation—are necessarily involved in every sentence and intrude at every turn. These rules alone make it much more difficult for an Englishman to learn to speak Welsh than for a Welshman to learn to speak English.

The general character of the Welsh language in composition is that of a certain stateliness, and even grandiloquence, the reverse of what would probably be expected by strangers who know for how long it has been the language of the peasantry alone and discountenanced by the higher classes. In its effect, it reminds a reader more of the Spanish than the German. It has been sometimes praised for its conciseness, but in its present state it may be much more justly characterised as diffuse. The words in the first paragraph of the 'Pilgrim's Progress,' "I looked and saw him open the book and read therein, and as he read he wept and trembled," are thus rendered in the Welsh translation by Thomas Jones, published at Shrewsbury in 1699, "Edrychais a gwelais ef yn egor y Llyfr ac yn darllain ynddo; a phan ddarllenodd ef wŷlodd a chrynnodd." In this there are exactly as many words as in the original, namely, nineteen; but in the translation published at Caermarthen in 1771, and reprinted in 1854, the passage stands thus, "Mi a edrychais ac a'i gwelais ef yn agor y llyfr ac yn darllen ynddo, ac fel yr oedd efe yn darllen fe wylodd ac a grynodd," and the number of words is twenty-eight. The same proportions seem to prevail between the language of the two translations in general.

The Welsh are strongly attached to their language. The Irish, so vehemently opposed to the Saxon in religion and politics, are in the matter of language far from obstinate. Daniel O'Connell, the patriotic orator, and Moore, the patriotic poet, were ignorant and careless of the Celtic tongue. It is said that the peasantry are so anxious to secure to their children that mastery of English of which they feel the want themselves, that they have a forfeit for speaking Irish, and enforce it on the children in their cabins with as much severity as a forfeit of a similar kind is enforced on the pupils in an English boarding-school. Under the influence of this feeling the Celtic language of Ireland appears to be slowly but surely losing ground, while the English language is indebted to Ireland for some of its finest poets and novelists, and most brilliant orators, with a long array of literary labourers of a less ambitious class. With Wales all this is different. The Commissioners of Inquiry into the state of Education in Wales, give it as their opinion in their official report, that "the Welshman possesses a mastery over his own language far beyond that which the Englishman of the same degree has over his;" and that "readiness and propriety of expression to an extent more than merely colloquial, is a feature in the intellectual character of the Welsh." But the Welsh are eloquent and poetical in their own language only. They have contributed no bard, no orator, no historian, no dramatist, no preacher, of the first, or the second, or even the third rank, to the literature of England.

The use of two languages in the same country cannot but be considered as an evil, for it is an element not of concord but of discord. The experience of the continent, in the case of German and Danish, and of German and Hungarian, shows that under certain circumstances it may even become a source of civil war. It is an admitted fact that antipathy and animosity towards the Saxon still lurk among that portion of the Welsh population to whom English is a language either entirely unknown, or known but imperfectly. There is a well-authenticated story that in the time of the Commonwealth, Sir Edward Stradling, of St. Donat's Castle, flying from the victorious Roundheads after a lost battle, came to the river Taff, and finding the bridge broken down, asked in the English language of a Welsh peasant who was standing near, where he might safely ford the stream. He was told in reply, "Keep straight on, for that is the shortest and best way to thy home." Sir Edward rode on to the bank, and chanced before entering the water to speak a few words to his soldiers in Welsh, on which the peasant, perceiving he was not an Englishman, called out in haste to him not to enter the stream at that point, for if so he would lose his life. There was a whirlpool on the spot, to which the malignant peasant, when he thought Sir Edward a Saxon, had directed the stranger with a view to drown him. Such feelings are far from extinct, even in modern times, unless those who are well acquainted with Wales are much mistaken.

The Welsh language is now in a very flourishing state. The fate of its neighbour, the Cornish, which gradually perished of mere neglect, led to the supposition that the Welsh would also disappear from the same cause; and indeed Mr. Wynne, the president of the Asiatic Society, himself a Welshman, referred to the decline of Welsh as a proof of the efficacy of the non-interference system in such cases, in a discussion on the subject of endeavouring to introduce the English in the place of some of the native languages of India. More than a century ago, Goronwy Owen, the Welsh poet, related in one of his letters (printed in the 'Cambrian Register'), that in a discussion on the Welsh language with another Welshman, Owen, the translator of Juvenal into English, "the wicked imp, with an air of complacency and satisfaction, said there was nothing in it worth reading, and that to his certain knowledge the English daily got ground of it, and he doubted not but in a hundred years it would be quite lost." The experience of the time that has since elapsed has shown that Mr. Owen was mistaken. "For upwards of ten centuries," says the Rev. W. J. Rees, in an address delivered in 1821 on the formation of the Cambrian Society in Gwent, "since the reign of Offa, who made his celebrated dyke to prevent incursions of the Welsh into his territories, the Welsh language has receded comparatively but little within the boundary, especially in some parts of North Wales; and in other districts, when the long lapse of time since the conquest by Edward I., and the intimate incorporation by Henry VIII., and the great encouragement given for the attainment of the English language are considered, it has gained less ground than could be expected. An Englishman travelling the public roads of the principality often meets with persons who speak English, and those whom he has occasion to address at the inns are able to accommodate themselves to his language: the gentry he may visit speak English, and those who call upon them probably use the same language in his hearing; and from these slight facts which come to his knowledge, he erroneously concludes that the English is the prevailing language of the country. It is only one who has resided a long time in the interior, having intercourse with the common people, that can form a true estimate of the extent of the Welsh language; and most persons will readily assent to the truth of the assertion, that the Welsh is the sole living speech not only of thousands, but of tens of thousands, and even of some hundreds of thousands of the inhabitants of the principality." ('Cambro-Briton,' vol. iii., p. 229.) It not only holds its ground in the Old World, but has emigrated to the New. While Dr. Macleod, in the preface to his 'Leabhar nan Cnoc,' exulted in the hope that if Gaelic is destined to perish in the Highlands, it will survive beyond the Atlantic in the living speech of numbers greater than ever spoke it in Europe, the Rev. T. Price, in his 'Hanes Cymru,' related with similar exultation that he had received from America some numbers of a Welsh periodical, the 'Cyfaill yr Hen Wlad,' or 'Friend of the Old Country,' which was publishing at New York. This progress continues. In an account of the press in the United States in 1861 it is mentioned that five Welsh newspapers are printed in that country, a circumstance which may probably lead some future Celtic historian to infer the truth of the belief, so firmly entertained by some Welshmen, that the language has flourished on the American continent since the days of Madoc. At the same time the periodical press of Wales itself is increasing yearly, while in the first number which ever appeared of a Welsh newspaper, not fifty years ago, a notion was stated that the language would hardly survive that generation. Eisteddvods or Bardic meetings, formerly rare, are now frequent and more and more popular. The call for bishops who understand the Welsh language has been loud enough to compel the attention of the English cabinet. At the present moment the patriotic aspiration so often on the lips of Welshmen, "Oes y byd i'r iaith Gymreig,"—"May the Welsh language last as long as the world,"—appears in small danger of non-fulfilment.

If it be really decided that the language of "some hundreds of thousands" is to continue to be cultivated amidst its native mountains, side by side with the language of sixty millions, to which fresh millions are added every year, care should be taken to avoid the disadvantages that might arise from such a state of things. The preservation of the old language ought to be combined with the cultivation of that which has grown up beside it,—of the great English language that has put a girdle round the earth, and is now spoken by mighty communities in each quarter of the world, and on the shores of every ocean. The "Cymro uniaith" "the Welshman of one language,"—a phrase in common use—is not necessarily more patriotic than the Welshman of two languages; but he is, by a great deal, a member of society less capable of aiding others and of aiding himself. Were the English language introduced into every school, and were the youth of Wales induced to make themselves thoroughly familiar with it, much good would undoubtedly be the result. The acquisition of the general language of the empire, of the language of great cities and high civilisation, and ample stores of learning, would open a new field to the abilities of many a young Welshman, whose ignorance of any but his native language confines him to a small circle and a narrow career—the general diffusion of English would invite more frequent visitors from England to the lovely and romantic scenery of the principality, and a new era of more cheerful prosperity might dawn upon Wales.

LITERATURE.—The quotation is peculiarly happy which was prefixed to a magazine entitled 'The Cambro-Briton,' devoted to the cultivation of Welsh literature: "Nulli quidem mihi satis eruditi videntur quibus nostra ignota sunt."

The history of the literature of Wales is as peculiar as that of its language. It commences with poems ascribed to the 6th century, a period of almost classical antiquity, to which no living language of the Teutonic or Sclavonic families can be traced. It flourished undoubtedly in the 12th century, and its "golden age" is referred to a date at which no English literature could be in existence, because the English language was as yet unborn. For the last six or seven hundred years its course may be distinctly traced, almost the "solitary pride" of a nation, that, amidst all obstacles and struggles, has been remarkably constant in its attachment to letters. It is true that the value of this literature is not to be compared for an instant with the value of our own, but it is a literature eminently curious and eminently British; and the apathy can hardly be explained with credit to English scholars that has allowed the subject to remain as it has, in almost total obscurity and neglect.

Perhaps the most valid excuse that can be pleaded is that obstacles to investigation were offered in the very quarter from which assistance might be looked for. A mass of unfounded and uncritical statement on the subject of Welsh antiquities is in existence and in print, which obstructs in the most annoying way the endeavour to arrive at a clear view of the subject. "A Scotsman," says Dr. Johnson, "must be a sturdy moralist indeed if he loves not Scotland better than truth." "How justly," says Edward Williams, or Iolo Morganwg, the most eminent Welsh antiquary of the 19th century, "might he have said the same thing of every Welsh antiquary that has hitherto appeared in the world." ('Cambrian Journal,' for 1860, page 18.) "How many truly learned and ingenious literary gentlemen," says the same writer in another place, "applied to Mr. Evans and his *fib-monger*, Lewis Morris, for information relating to Welsh literature and Welsh antiquities, and how many of the most glaring falsehoods have they had in return from these fellows," whose alleged ignorance and bad faith he proceeds to expose. But the very Iolo Morganwg whose words we have quoted, and who up to his death, in 1826, was, and is even now regarded by many as the chief authority on Welsh literature, is pointed out by others as absolutely still less worthy of confidence than any Welsh antiquary who preceded him. Not only therefore is the entrance into the cavern of Welsh antiquities dark and difficult, but the guides are not to be trusted. The national practice has not been in accordance with the national motto of Wales, "Y Gwir yn erbyn y Byd," "Truth against the world."

Another obstacle, though an inferior one, has been the difficulty of arriving at the materials for forming a judgment. The Welsh, as has been said, claim to be in possession of a body of poetical compositions extending over a period of thirteen hundred years. Till the commencement of the 19th century almost all the compositions for which this antiquity is claimed remained buried in the libraries of colleges and of private individuals, some so difficult of access, that Lhuyd, the author of the 'Archæologia Britannica,' who spent his life in researches into Celtic literature, was never able to obtain a sight of some of the most interesting. This reproach was removed, after ineffectual appeals to the patriotism of the gentry of Wales, by the liberality of Owen Jones, a furrier in Thames Street, father of Owen Jones, the architect, so well-known by his publications on the 'Alhambra,' and his restoration of it at the Crystal Palace of Sydenham. At the expense of more than a thousand pounds Mr. Jones, the elder, collected and published, in 1801 and subsequent years, in three volumes, under the title of 'The Myvyrian Archaiology of Wales,' the chief productions of Welsh literature for nearly nine hundred years, from about 500 to 1400. In this task he was assisted by Edward Williams, better known by the name of Iolo Morganwg, or Edward of Glamorgan, already mentioned, and by Dr. Owen, afterwards Dr. Owen Pughe. The enterprise was by no means undertaken too soon. "A number of manuscripts equal to what now remains," says Owen in the fourteenth volume of the 'Archæologia' of the Antiquarian Society, "hath perished through neglect within the last two hundred years, that is to say, since the higher ranks of Welshmen have withdrawn their patronage from the cultivation of the literature of their native country. We have still upwards of two thousand manuscript books of various ages, from the beginning of the 9th to the close of the 16th century." By the publication of the 'Myvyrian Archaiology' a vast mass of materials was placed out of danger, but it did not comprise the whole of what Jones intended to publish,—in the library of the British Museum, no less than eighty volumes of transcripts are now deposited which were intended for a continuation of the work. After the cessation of Jones's exertions, the old apathy returned, and more than thirty years elapsed before, in 1837, an association was set on foot on the model of the Camden and similar societies, and under the name of the Welsh Manuscript Society, for the purpose of publishing manuscripts, whether in Welsh or other languages, connected with Wales. The important provision was made in the rules, that the works in Welsh were to be accompanied with translations. The Society has not been so active as it promised. Since its foundation, it has scarcely issued five volumes, and some of them are of a mere antiquarian and genealogical cast. The most important is that entitled 'The Iolo MSS.,' a volume of selections from the materials collected by Iolo Morganwg for the continuation of the 'Myvyrian Archaiology.' At present (in 1861) it is said in the 'Cambrian Journal' that measures have been taken for "re-invigorating" the society, and we heartily wish them success.

In the publications of this society the second step was begun to be taken of the three which are requisite to bring the literature of Wales fairly before the world. The first is, the publication of its monuments, as indispensable materials for all that is to follow; the second, the rendering of them accessible, by translations, to those who have not the opportunity of acquiring, in addition to the knowledge of the Welsh language as it now is, that of all its variations from the time of King Arthur. The third will be, that of applying a judicious criticism to these materials; of comparing, elucidating, and investigating; separating the genuine from the spurious; and deciding their value. When all this has been done, and not before, it will be possible to take a satisfactory survey of the history of early Welsh literature, in which is involved the history of two of the most interesting points of modern literature in general, the origin of rhyme and the origin of romantic fiction. Under present circumstances many questions of interest must be left doubtful.

The history of Welsh literature may be divided into four periods: from the earliest times to the Norman conquest of England in 1066,—from the Norman conquest to the Reformation, which nearly coincides with the incorporation of Wales with England in the reign of Henry VIII., in 1536,—from the Reformation to the commencement of the reign of George III., in 1760,—and from 1760 to the present time.

The First Period, 1066.—The Welsh, it has been already stated, claim to be in possession of several poetic compositions of the date of the 6th century, and these compositions are in rhyme, which would be, as far as is at present known, the earliest instances of that kind of composition in Europe. The whole of them were printed in the 'Myvyrian Archaiology,' in which they occupy one hundred and eighty-eight pages of double columns, nothing of which beyond a few specimens had appeared in print before. The authors to whom they are attributed are:—Aneurin, who is supposed to have lived from 510 to 560; Taliesin, the Chief of Bards, from 520 to 570; Llywarch Hen, or Llywarch the Old, from 550 to 640; and Myrddin, or Merlin, from 530 to 600; besides Gwyddno, Gwilym ab Don, Golyddan, and others of minor importance.

The authenticity of these poems having been impugned by two celebrated antagonists of the Celts, by Pinkerton, in his preface to Barbour, and by Laing, in a note to his 'Dissertation on Ossian,' it was maintained by Sharon Turner, the Anglo-Saxon scholar, in his 'Vindication of the Genuineness of the Antient British Poems of Aneurin, Taliesin, Llywarch Hen, and Merddin,' first published separately in 1803, and since appended to the successive editions of his 'History of the Anglo-Saxons.'

In this treatise Mr. Turner asserted the genuineness of the ancient poems on both internal and external evidence. The oldest copy of any of them extant occurs in an ancient manuscript called 'The Black-Book of Carmarthen,' formerly preserved in the library of the Vaughans at Hengwrt in Merionethshire, which was brought together by Robert Vaughan, who died in 1666. This book is believed, by competent judges, to be of the 12th century; so that if forged at all the poems must have been forged as far back as that period, while in fact they are alluded to as ancient by writers of the centuries immediately following. If fabricated at that time, it is probable that they would have contained allusions to the popular legends respecting King Arthur, whose name had then become known throughout Europe as that of the hero of romantic tradition; while these compositions, professing to be written by contemporaries of Arthur, and frequently referring to his life and actions, always mention him in a sober, unexaggerated, strain, perfectly consistent with the light in which he is presented by authentic history. Finally the language is of an extremely antiquated cast, often obscure, and sometimes unintelligible, and altogether different from that of compositions known to be of the 12th century.

The weak point in Mr. Turner's argument is that it proves, or assumes to prove, too much. If all that he advances were valid, the whole of the poems ascribed to the primitive bards would be genuine, but in fact some are demonstrably otherwise. There is a remarkable passage in Evans's 'Specimens of the British Bards,' published in 1763, every word of which has been confirmed by the most recent investigations. Speaking of Taliesin, Evans says, "There are many spurious pieces fathered on this bard in a great many hands in North Wales, but these are all forged, either by the monks to answer the purpose of the Church of Rome, or by the British bards in the time of the late princes of Wales to spirit up their countrymen against the English, which any body versed in the language may easily find by the style and matter." These pieces are those made public in the 'Myvyrian Archaiology,' on the judicious principle laid down by its editors, of putting in print and on record whatever was asserted to be of a certain degree of antiquity, without any preliminary inquiry into the justice of its claims. The opportunity thus afforded of subjecting them to criticism has been taken.

The two works in which the subject has been treated with the greatest care since Mr. Turner's time, are 'The Literature of the Kymry,' by Mr. Thomas Stephens, of Merthyr-Tydvil, published in 1849, and 'Taliesin, or the Bards and Druids of Britain,' by Mr. D. W. Nash, of the Royal Society of Literature, published in 1858. Mr. Stephens is a Welshman of learning and of a critical habit of mind and a candour not always met with among his countrymen. Mr. Nash is an Englishman who has studied Welsh literature with peculiar attention and success. The conclusions at which they arrive are almost the same. Of the seventy-seven poems ascribed to Taliesin, and printed in the 'Myvyrian Archaiology,' Mr. Stephens considers fifty-seven to be demonstrably spurious, and of the remaining twenty there are only twelve that he assigns with confidence to the time of Taliesin. Mr. Nash gives translations of more than fifty of these poems, many of which had never appeared before in any other language than Welsh; and the mere perusal of them is sufficient to show that the notion of their belonging to the 6th century is absurd. Poems which had been represented by some Welsh writers as full of allusions to the rites of Druidism are full of allusions to Roman Catholic theology, partly couched in mediæval Latin. One instance will be sufficient to show the nature of the arguments. There is a poem, ascribed to Taliesin, prophetic of the fall of his country, in which occur the lines which are on the lips of every Welshman, and have been cited oftener than any other lines in the language:—

"Eu Ner a molant,
Eu hiaith a gadwant,
Eu tir a gollant
Ond gwyllt Walia."

"Their God they shall adore,
Their language they shall keep,
Their country they shall lose
Except wild Wales."

Such a prophecy made in the 6th century, when the Saxons were contending with King Arthur, and the struggle between the races was still going on in Cumberland and elsewhere, would indeed be remarkable, while in the 12th century it would be that not unusual phenomenon, a prophecy after the event. The language of the poem is so free from obscurity, that it is said, in the periodical entitled 'Taliesin,' for 1861, to be "intelligible this day to the children of Aberystwith." Many of the proper names which occur in the poem have a very peculiar character. They are in a Latinised form, "Troia" for Troy, "Sermania" for Germany, "Sacsonia" for Saxony, "Sabrina" for the Severn, and, in the passage quoted, "Walia" for Wales. Can it be supposed that the Saxon term for Wales was in common use in the 6th century? that it had been already Latinised? and, lastly, that a Welsh bard of the court of King Arthur borrowed the Latinised form of the name of his country from his country's foes to introduce in his patriotic poem? All these circumstances appear to indicate the composition of the lines by a mediæval monk, and the supposition is strengthened by the mention of Troy as the land of the origin of the Britons, a prevalent belief after the time of Geoffrey of Monmouth, who flourished under Henry I.

While the authenticity of some of the most interesting supposed relics of Taliesin must therefore be given up, the critics who impugn them concur in believing that other portions are really genuine. The Rev. Evan Evans in his 'Specimens,' Mr. Stephens, Mr. Nash, and others, are all of this opinion. Unfortunately, those of the seventy-seven which they respect are of a very small degree of interest. Taliesin, as he has descended to us, is certainly no Ossian—taking as the proper representative of the Gaelic bard the Ossian of Macpherson—nor is he even equal to Aneurin, still less to Llywarch Hen.

Many of the fictitious poems ascribed to Taliesin occur in a strange legend of his life, which is itself a singular relic of literature. The traditions of the great bard, relied on by Williams in his 'Lives of Eminent Welshmen,' represent him as the son of a saint, a certain St. Henwg, and educated at the College of St. Cadog. Much of his time was spent at the court of Urien Rheged, a chieftain to whom many of his poems are addressed, but being once fishing at sea in a skin coracle he was seized by Irish pirates, who bore away with him towards Ireland. Escaping from them in his coracle, while they were engaged in drunken revelry, he was tossed about at the mercy of the waves till the coracle stuck to the point of a pole in the weir of Gwyddno, prince of Cardigan at Aberdyvi. At the court of Gwyddno, who was himself a poet, he remained till the memorable event of the destruction of Gwyddno's country, in the beginning of the 6th century, by an inundation of the sea, which converted what was dry land into the present Cardigan Bay. After this time Taliesin went to the court of King Arthur at Caerleon on Usk, and on his death was interred at the spot near Aberystwith which still goes by the name of Bedd Taliesin (Taliesin's grave).

The chief incident in this life appears in an altered form in the legend or romance which is printed in Welsh in the 'Myvyrian Archaiology,' and in Welsh, with an English translation, in the fifth volume of the 'Cambrian Quarterly Magazine,' and in Lady Charlotte Guest's 'Mabinogion.' According to this story, Gwion the Little, a boy who was employed by Keridwen, a witch of Meirion, or Merionethshire, to watch a magic cauldron in which she was preparing a concoction that was to bestow knowledge and genius on her son, incurred the vengeance of his mistress by involuntarily drinking the three blessed drops which were to produce these wonderful effects. Of course he became endowed with sudden wisdom, and fled from the wrath of Keridwen, who at once pursued him. He fled in the form of a hare, she pursued in that of a hound; when nearly overtaken, he turned to a fish, and she to an otter; then he to a sparrow, and she to a hawk; and he was finally swallowed in the form of a grain of wheat by Keridwen, in the form of a hen. After nine months she was delivered of him again, and he was so handsome that, unwilling directly to take his life, she tied him up in a leathern bag and threw him into the sea, from which he was rescued by Prince Elphin, the son of Gwyddno, who, fishing for salmon at the weir of Aberdyvi, caught a child instead. The prince looked disappointed in consequence, and was addressed in consolation by the miraculous infant in a strain of poetry, the merits of which are anything but miraculous. This infant had such a splendid forehead that he received the name of Taliesin, which bears that meaning in Welsh. The narrative proceeds with a medley of incidents, interspersed with poems of little or no merit put into the mouth of Taliesin, and inextricably connected with the circumstances of the tale. The whole story appears to be of the same character with those which were told of Virgil in the middle ages,—a wildly fictitious narrative fastened on a distinguished name, from the wish to give it an air of authenticity in the eyes of ignorance. It may be taken therefore as a proof that, at the time of its invention, the name of Taliesin was current in popular tradition as that of the great poet of Wales; while the fact that the poems ascribed to him in it are as spurious as the adventures are impossible, is no stronger proof against the existence of the real works of a real Taliesin, than the stories about Virgil's feats of necromancy are proof of the spuriousness of the Georgics and the Æneid. Some of the incidents regarding the magic cauldron are traced by Mr. Nash to Irish and Icelandic fiction, and some, as the pursuit of Keridwen, bear a striking resemblance to passages in the 'Arabian Nights.' The tale of Taliesin, and of course the poetry inserted in it, are traced with tolerable certainty to one Thomas ab Einion, a priest who flourished in the 12th century.

Many of the poems ascribed to Aneurin are shown to be spurious by modern criticism, but that entitled 'The Gododin,' bears very strong marks of authenticity. Aneurin was one of the northern Britons of Strath Clyde, who have left to that part of the district they inhabited the name of Cumberland, in token that it was once in possession of a section of the Cymry. In this poem he laments the defeat of his countrymen by the Saxons at the battle of Cattraeth, in consequence of their having partaken too freely of the mead before joining in combat. He commemorates many obscure chieftains who fell on the occasion in language which seems dictated by the freshness of grief. A portion of this poem has been translated by Gray; a version of the whole was inserted by the Rev. Edward Davies in his 'Mythology of the Druids;' and a translation of the whole works of Aneurin, 'The Gododin' and the 'Odes of the Months,' was published in 1820 by Mr. Probert. A fresh translation of 'The Gododin' was published in 1858, by the Rev. John Williams ap Ithel, the editor of the 'Cambrian Journal.' It may be taken as a proof of the authenticity of the original that the translators have had an opportunity of disputing, not only about the meaning of several of the passages, but even of the whole poem. The Rev. Edward Davies maintains that it relates not to the battle of Cattraeth, but to the massacre of the Welsh chieftains by order of Hengist at a banquet at Stonehenge.

'The Heroic Elegies and other Pieces of Llywarch Hen, Prince of the Cumbrian Britons, with a literal translation by William Owen,' were published in 1792. Llywarch Hen, like Aneurin, was one of the warriors of Strath Clyde, and, like him, was driven to Wales by the successes of the Saxons. His poems are by far the finest of those ascribed to the primitive bards. Southey, who remarks that "their authenticity has been proved by Mr. Turner; and they are exceedingly curious, and some of the oldest remains of Celtic poetry," observes, in the notes to his 'Sir Thomas More,' that their "general strain is as melancholy as it is rude." According to Welsh tradition Llywarch Hen, or Llywarch the Old, lived to the age of a hundred and fifty. His four-and-twenty sons and three daughters all died before him, as was natural in that case, but in his 'Elegy on Old Age and the Loss of his Sons,' he enumerates many who had perished in war, and accuses himself of having caused their destruction. The staple of his poetry is bitter complaint of the woes of age. "Those that loved me once now love me not," he exclaims. "Ah death, why will he not befriend me? I am outrageous! I am loathsome! I am old." Some 'Lines to the Cuckoo in the Vale of Cuawg' which are now ascribed to a certain Mabclaf ap Llywarch, who lived towards the close of the 14th century, are in precisely the same impressive strain.

Some of the remaining poems in the 'Myvyrian Archaiology,' are ascribed to two Merddyns, who have been amalgamated and made into the Merlin of romance. The same work contains a considerable number of anonymous pieces ascribed to the earliest bards; but the language is sufficient to show that their genuineness is more than doubtful.

Strange to say, the only collection that has yet been published of the primitive bards of Britain, with a translation and explanatory and critical notes, is that by a Frenchman, the Count Hersart de la Villemarqué, 'Poëmes des Bardes Bretons du VI$^{\text{ième}}$ siècle, traduits pour la première fois avec le texte en régard,' Paris, 1850. The ingenious critic, himself a Breton, and the first collector of the ballads of Brittany, has unfortunately adopted the singular idea of printing his Welsh text neither according to the ancient nor the modern Welsh spelling, but according to the system proposed for the Breton by Legonidec, and the result is that it requires a separate study to decipher a line of his text. His prefaces and notes are written in a strain of hyperbolic enthusiasm, but have a foundation of good sense. He omits almost all of the poems of Taliesin as spurious, and he quotes the names of the French critics Fauriel, Ampère, and Magnin as concurring in the opinion that those which he gives are authentic.

The earliest monument of Welsh prose would, if it were genuine, be the "Wisdom of Cadog the Wise," a collection of proverbs ascribed to St. Cadog, who is said to have lived in the 6th century, and to have been the friend and instructor of Taliesin, and one of the ornaments of the court of King Arthur. They are printed in the 'Myvyrian Archaiology,' and in the Iolo MSS. there is a collection of fables and tales ascribed to the same St. Cadog. One of the tales is the story of the man who hastily slew his faithful dog from the erroneous supposition that it had killed his child, whom it had in reality defended from a serpent. This story, which is told by St. Cadog, without name of person or place, is now the most popular legend of Wales, and sheds an additional charm over the scenery of Bedd Gelert, but the Gelert of the modern tradition, and of Spencer's ballad, is 'The gift of royal John' to Llewelyn ab Jorwerth, who married a daughter of King John of England. There can be no doubt that the language of the narrative in the Iolo MSS. is nearer to the time of Llewelyn ab Jorwerth than to that of St. Cadog, but unfortunately the original of the story is to be found in Sanskrit.

The earliest Welsh prose of which the authenticity is unquestioned, is the collection of the laws of King Hywel Dda, or Howel the Good, who died in 748, after a reign of forty years, during the last seven of which he was monarch of all Wales. This code is divided into the laws of the court and the laws of the country, and under both heads it comprises a quantity of matter curiously illustrative of the manners of the times; it is assumed, for instance, that there is one cat in each village, and it is estimated as of precisely the same value as a sheep. The bards are endowed with many privileges, extending to receiving dues on marriages, to exemption from bearing arms, and to various other sources of emolument and honour. The leading feature of the legislation is that every crime is punishable by a fine, even that of the murder of the king himself, which is to be atoned for, among other things, by "three golden cups, with covers each as broad as the offender's face," and as "thick as the thumb of a ploughman who has been nine years in that employment, three silver rods of the same height as the king, and as thick as his thumb," &c. &c. These laws were first published in a somewhat uncritical fashion in 1730, in Wotton's 'Leges Wallicæ;' the last edition, in Welsh and English, is comprised in the 'Ancient Laws and Institutes of Wales,' issued in 1841 by the Record Commission, and edited by Aneurin Owen, the son of Owen Pughe, a much severer and more acute critic than his father. The earliest manuscript is of the 12th century; and Owen cautiously describes his text as the "Laws, *supposed* to be enacted by Howel the Good, modified by subsequent regulations under the native princes prior to the conquest by Edward I." "References are made," he adds, "to laws ordained by Dyvnwal Moelmud, an ancient Regulus in the west, and some triads are ascribed to him; but these, although they contain ordinances likely to obtain in a primitive state of society, have no warrant of authenticity. We find mention of laws by Marsia, of an equally apocryphal origin." The laws of Dyvnwal are supposed by some Welsh writers to have been prevalent in Britain 400 years *before* Christ. The triads here mentioned belong to the historical triads, of which a portion is admitted on all hands to be of at least as late a date as the reign of King Edward I., and they will therefore be treated of in our notice of the second era of Welsh literature, commencing from the date of the Norman Conquest.

Second Period—1066-1536. The epoch of the Norman Conquest of England is one strongly marked in the literature as well as the history of Wales. Harold, the last of the Saxons, had overrun the country, and reduced it under princes subordinate to himself, in 1063, only three years prior to his own overthrow at Hastings. Two of the native princes, who were re-established on their thrones before the close of the 11th century, Gruffydd ab Cynan, prince of North Wales, and Rhys ab Tewdwr, prince of South Wales, came from abroad, the one from Ireland, and the other from Brittany, where two kindred Celtic nations were at that time in close intercourse with the Danes and the Normans. Gruffydd ab Cynan gave birth to a new era in Welsh poetry, and Rhys ab Tewdwr may have had some influence in the production of the most interesting monument of Welsh prose—the stories of King Arthur, whose name was for so many centuries a household word on the lips of the English as well as the Welsh.

The name of Arthur is first mentioned in the Latin chronicle of Nennius, who also mentions the name of the earliest bards, Taliesin, Talhaiarn, and others. The oldest manuscript of Nennius, which is in the Vatican, is assigned by its editor and translator, the Rev. William Gunn, to the 10th century. But the Arthur of Nennius is very different from the Arthur of romance, who first appears in the pages of Geoffrey of Monmouth. Before proceeding, however, to Geoffrey, who wrote in Latin, some mention should be made of the earliest of Welsh chroniclers, Caradoc of Llancarvan.

The history of the monk of Llancarvan contains the annals of Wales from the death of Cadwallader, A. D. 682 or 689, to the times of Caradoc himself, about the middle of the 12th century. It was continued, as was the custom with monkish chronicles, by other hands, and a good deal more was added in the English translation made about 1557 by the Welsh antiquary, Humphrey Llwyd, and published by Dr. Powell in 1584. The original Welsh remained in manuscript till included in the second volume of the 'Myvyrian Archaiology.' A different "recension" of it is known under the name of 'Brut y Tywysogion' or 'Chronicle of the Princes,' and was printed in Welsh and English in 1860 in the collection issued under the authority of the Master of the Rolls. The chronicle of Caradoc is one of the less attractive kind of monkish histories, dry and jejune like the 'Anglo-Saxon Chronicle,' which goes over much of the same period, but affording a useful skeleton and ground-work for less succinct historians. It has never emerged into much notice.

Far different was the character and the fate of the 'History of the Britons,' by Geoffrey of Monmouth, archdeacon of Monmouth, and bishop of St. Asaph, who was consecrated to his bishopric in 1152, and died in 1154. Geoffrey closes his narrative by the death of Cadwallader, at which Caradoc begins, and tells us that he left the story there on purpose for his friend Caradoc to continue. His 'History of the Britons' opens with the destruction of Troy, and the coming of Brutus, the coloniser of England, from Troy to Britain; and goes on, through the stories of Locrine and Lear, and Cymbeline and Gorboduc, to the legends of King Arthur and his conquests, and the prophecies of the enchanter Merlin. The work had a wonderful and a sudden success. As it is dedicated to Robert of Gloucester, the illegitimate son of Henry I., it must have been issued before 1147, the date of his death; and Alanus de Insulis, a Breton writer, who died in 1187, speaks of Arthur as then universally known. "Whither," he exclaims, "has not the name of Arthur the Briton been carried by Fame? What region of Christendom has it not reached? Arthur is almost better known to the Oriental nations than to the Britons themselves, as our pilgrims returning from the East declare." There was, doubtless, exaggeration in this, but there was doubtless also some foundation in truth; and the work of Geoffrey of Monmouth is the main source of the fame of Arthur. Translated and versified by Wace and Layamon, it became popular in French and English. For many centuries the story of Brutus, whose name is first mentioned by Nennius, passed for authentic history: in the pedigree of Henry VII., drawn up for him by Welsh heralds, the line of the Tudors is traced to Brutus as its founder; and even so far onward as in the time of Milton, the great poet gave way to his inclination to insert, though with an apology, these poetic stories in his history of England. With the poets, indeed, the success of the story of Geoffrey of Monmouth is still prolonged, and has burst out into fresh brilliancy in our own generation. The greatest work of Shakspere is founded on the legend of King Lear. Both Milton and Dryden projected an epic on the story of King Arthur, and Pope an epic on the story of Brutus. Walter Scott, who lamented that the court of Charles had

> "The world defrauded of the high design"

of Dryden, himself paid tribute to Arthurian fiction in his 'Bridal of Triermain.' In our own days Bulwer Lytton has given us his finest poetry in his epic of 'King Arthur,' and Alfred Tennyson has achieved one of his brightest triumphs in his 'Idylls of the King.'

Geoffrey of Monmouth was attacked with singular vigour by a contemporary antagonist—the chronicler, William of Newburgh. "In our days," says the critic, "a writer has emerged, who strings together the most ridiculous figments about the Britons, raising them, with impudent vanity, above the Macedonians and Romans. Geoffrey is the name of this man, who is now called 'Arthur's Geoffrey' (Galfridus hic dictus est, agnomen habens Arthuri), because taking some fables of Arthur from the original figments of the Britons, and adding others of his own, he has coloured them up in the Latin language, and decked them with the name of a genuine history." It will be noticed that the worthy chronicler, who adds more to the same purpose, admits in this passage that the object of his indignation did not entirely invent his narrative, substance, details, and all, but that some "ridiculous figments" about King Arthur were current before he took pen in hand. There must therefore have been Welsh traditions on the subject.

The account which Geoffrey himself gives of the origin of his history is this: that Walter Calenius, archdeacon of Oxford, finding a book in Brittany on the deeds of King Arthur, gave it to him to translate, having a favourable opinion of his Latin style, and that his work is neither more nor less than a version of this original. It is so evident that if he wished his production to pass for a history, it was advisable to say something of this kind, and it has been so customary for writers of fiction to do so, from before Tirant the White down to after Don Quixote, that this statement carries no great weight in itself. At first sight it seems confirmed by the fact that there is a book in Welsh passing by the name of the 'Chronicle of Tysilio,' which corresponds exactly with Geoffrey of Monmouth. Unluckily, however, it is evidently translated from the Latin, and at the end of the manuscript containing it is this singular note: "I, Walter, archdeacon of Oxford, turned this book from Welsh into Latin, and in my old age I turned it again from Latin into Welsh." The perplexity is therefore only increased by a statement which introduces the name of Walter, the archdeacon, not merely as the patron of Geoffrey, but as himself the translator. There is fresh material for controversy in the question whether the book said to have been found in Brittany may not have been in Breton, instead of Welsh, and both Mr. Thomas Wright, and Mr. Stephens, of Merthyr Tydvil, have arguments in favour of the Armorican origin of the legend of Arthur, but no such book is to be found in the one language any more than in the other. George Ellis, the friend of Sir Walter Scott, in the introduction to his 'Specimens of the early English Romances,' in which there is an admirable analysis of Geoffrey of Monmouth, gives reasons for believing that his history was really translated from a Welsh original.

There are still extant in Welsh a series of chivalric legends relating to the time of King Arthur and the Round Table, which may possibly have existed in a rude shape before the time of Geoffrey of Monmouth, and furnished him with some of his materials. In their present form they are much more elegant and finished than in his history, and embrace stories and particulars that he would hardly have passed over had he known them. These narratives now go by the general name of the 'Mabinogion,' or Children's Tales, the name which may be appropriate to some being applied to all. They are contained in a splendid manuscript volume of more than 700 pages, in double columns, preserved in the library of Jesus College, at Oxford, and known by the name of the 'Red Book of Hergest,' from the place in which it was originally discovered. The date of its transcription has been assigned by antiquaries to about 1370, or the close of the 14th century; but towards the end of the volume there are inserted, it is supposed in his own handwriting, many of the poems of Lewis Glyn Cothi, who flourished in the 15th, after the invention of printing. Were the date of the composition of the tales no earlier than that of their transcription, they would not be original. The stories of the 'Knight of the Lion,' the 'Knight of the Sword,' 'Lancelot of the Lake,' and others which occur in Welsh prose in the 'Red Book of Hergest,' were extant in French verse from the pen of Chrétien de Troyes before 1200, and as early as 1225 the Arthurian tales had been translated from French verse into Icelandic prose, at the instance of King Hakon Hakonsson of Norway. It is to be observed also that the manuscript volume contains other tales than those belonging to the Arthurian cycle, 'Sir Bevis of Hampton,' the 'Seven Wise Masters of Rome,' and the 'History of Charlemagne.' This is pointed out in the valuable preface and notes appended to the edition of the 'Mabinogion' in Welsh and English, published in the years between 1838 and 1849, in three large volumes, by Lady Charlotte Guest, now Lady Charlotte Schreiber. The 'Mabinogion,' the most attractive lady's book in the Welsh language, has appropriately been edited by a lady, and the volumes are in typography and embellishment by far the handsomest that have ever issued from the Cambrian press.

On the whole, though there are arguments against it into which our limits will not permit us to enter, the preponderance of evidence seems to be in favour of the Welsh origin of the romantic fictions connected with the Round Table of King Arthur, and thus of the Welsh origin of chivalric fiction in general. The reasons in support have been ably summed up in an 'Essay on the influence of Welsh Tradition upon European Literature,' by Mr. J. D. Harding, who also refers to the high authority of a scholar whose view of the subject was taken from a different point—Mr. Panizzi, of the British Museum. In the celebrated 'Essay on the Narrative Poetry of the Italians,' prefixed to his edition of Boiardo and Ariosto. Mr. Panizzi states, as the result of his researches, that "All the chivalrous fictions since spread through Europe appear to have had their birth in Wales."

The narrative of Brutus and his expedition from Troy, given by Geoffrey of Monmouth, was, as we have seen, adopted for some centuries, in spite of the energetic protest of William of Newburgh, as the basis of popular English history. Yet it was totally inconsistent with another history of the colonisation of Britain, which, if we are to believe its supporters, was current long before Geoffrey of Monmouth, in the so-called Triads. These constitute the most peculiar feature in the whole of Welsh literature. A 'Triad' is the enumeration of three persons, or events, or observations, strung together in one short sentence by some thread of connection. This form of composition has been so popular among the Welsh that, brief as most of the Triads are, the collection of them occupies more than 170 pages in double columns in the 'Myvyrian Archaiology.' A few instances of Triads of different kinds and different ages, taken from the preface to Owen

Pughe's translation of Llywarch Hen, and other sources will show of what elegance they are susceptible.

"The three foundations of genius—the gift of God, man's exertion, and the events of life.

"The three primary requisites of genius—an eye that can see nature, a heart that can feel nature, and boldness that dares follow nature.

"The three supports of genius—strong mental endowment, memory, and learning.

"The three supports of genius—prosperity, social acquaintance, and praise.

"The three foundations of judgment—bold design, frequent practice, and frequent mistakes.

"The three fountains of knowledge—invention, study, and experience.

"The three indispensables of language—purity, copiousness, and aptness."

Other Triads are of a less general and more patriotic kind :—

"There are three things for which a Cymro should be willing to die—his country, his good name, and the truth, wherever it be.

"There are three things highly disgraceful to a Cymro—to look with one eye, to listen with one ear, and to defend with one hand.

"Three persons it especially behoves a Cymro to choose from his own country—his king, his wife, and his friend.

"Three things a Cymro ought to love beyond everything—the nation of the Cymry, the manners and customs of the Cymry, and the language of the Cymry."

The Triads are of all ages. There are instances of the throwing of ideas into threes in some of the poems of Llywarch Hen, and it is probable that some of the Triads of Proverbs attributed to St. Cadog are as ancient as anything in the language. But the oldest record of them is, we believe, in the Red Book of Hergest, supposed to be of the date of 1370, and the greater part are only extant in transcripts and books of miscellanies of the 16th and 17th centuries. They are peculiarly a class of composition to which any ingenious transcriber would be tempted to add something of his own. But with regard to the 'Triads,' which stand only on their merits, and of which some are as pointless as those we have quoted are pointed, the fact of their antiquity is of much less interest than with regard to the 'Historical Triads,' which form part of the class. The main value of these, of course, depends on their authenticity.

"The 'Historical Triads,'" says the Rev. T. Price, author of the 'History of Wales, "are extremely perplexing to the historian, as it is difficult to decide whether they are to be considered as authentic records, or merely as ingenious fabrications. The collection in which they were found was made by Thomas Jones, of Tregaron, about the close of the 16th century, a time when the Trojan origin of the Britons had scarcely been called in question, and yet the Triads gave a totally different and more rational account of the colonisation of Britain. The character of this Jones as an antiquary and genealogist scarcely admits a suspicion of forgery on his part; and the statement of Jones, respecting his being merely a transcriber, is also supported by certain indications of their being positively corrupted when he found them." The character of Jones was, however, one that was peculiarly liable to suspicion, if not to something worse. Mr. Thomas Jones of Tregaron was, according to Williams in his 'Lives of Eminent Welshmen,' an eminent robber on the highway, who later in life reformed, married a rich heiress, and became an exemplary justice of the peace for the county of Brecon. His life seems to have resembled that of his countryman, Sir Henry Morgan, the famous buccaneer, who closed his career in the reign of Charles II. as governor of Jamaica. Dr. Rhys, the Welsh lexicographer, pays a compliment to Jones in the preface to his dictionary as an eminent antiquarian and genealogist; but what his humbler neighbours thought of him may be inferred from the fact that his name still survives in popular tradition as that of a bandit and a conjuror. Mr. Thomas Jones of Tregaron is, in fact, no other than Twm Sion Catti, or Tom Jones Catty, who has been often denominated in recent times "the Welsh Rob Roy."

The statements of the 'Historical Triads' are the sole authority for much that has found its way into the works of recent writers on Wales, as if it were of the most unquestioned truth. According to these statements, Hu Gadarn, or Hu the Mighty, an ancient patriarch of the Cymry, was the first who brought the nation to the shores of Britain from a country called the Summer Land, and over a sea called the Hazy Sea. The Summer Land is decided by some to have been Constantinople, and by others the Crimea. In a speech by the Rev. R. W. Morgan at the Eisteddvod of Llangollen, in 1858, on presenting to the meeting a Corporal of the Welsh Fusiliers, who had served in the Crimean war, the orator remarked, "Very singular and instructive is the reflection that to the Crimea, whence our forefathers first under Hu Gadarn emigrated and colonised Britain, their children should from their British home return, a living nation and an imperishable tongue, to combat the gigantic oppressor of the North on his own soil, and to lay their ashes by the side of the tumuli of their ancestors." In short, there are modern Welsh scholars who believe in Hu Gadarn quite as firmly as their forefathers did in Brutus.

The statements of the Triads are, it is evident, directly at issue with those of Geoffrey of Monmouth, and if they were really in being during the centuries that elapsed between the reign of Henry I., which is the time of Geoffrey, and the reign of James I., which is the time of Twm Sion Catty, it seems hard to imagine why all Welsh antiquaries, heralds, and genealogists should have preserved so deep a silence on the subject. If, on the other hand, we suppose that Thomas Jones of Tregaron was a person of the same turn of mind as Thomas Chatterton of Bristol,—that he had a lively imagination, and a strong desire to impose the fruits of that imagination upon others for fact; if we suppose that a man of his far from strait-laced character was one of those "fib-mongers" who are denounced by Edward Williams as so abundant in Welsh literature, the mystery is at once explained. To support the authority of the Triads, however, a new authority has in the course of the last seventy years been brought forward in the shape of "Bardic Tradition," to which, however, it will be unnecessary to advert, till the fourth stage in the history of Welsh literature is reached.

In following the different ways in which the history of Wales has been treated, almost every important specimen of the prose literature of the second period has been already mentioned, with the exception of a remarkable piece of biography, the life of Gruffydd ab Cynan, the Welsh prince who revived Welsh poetry after the Norman Conquest. Gruffydd was Irish by birth, and by descent partly Scandinavian, having been born to his father during his exile in Ireland, where Cynan married the daughter of Anlaf or Olaf, the Dano-Irish king of Dublin. Gruffydd recovered the dominions of his ancestors in North Wales, in 1079, and, after various vicissitudes, in the course of which he was held for twelve years in captivity by the Norman Earl of Chester, died in possession of his princedom in 1137. In 1100 he held, at Caerwys, in North Wales, a famous Eisteddvod, or meeting of the bards, which forms an epoch in the history of Welsh literature. It was attended by numerous Irish bards and musicians, whom Gruffydd had invited; and he introduced, by the influence of these foreigners, the use of bag-pipes into Wales, where, however, after languishing for some centuries, they finally gave way before their constant competitor, the national harp. The influence of his Scandinavian mother, and the Scandinavian court he had seen at Dublin, may be traced in the love of war and the love of alliteration which became more conspicuous than ever in Welsh poetry after the Eisteddvod of Gruffydd ab Cynan.

From the time of Gruffydd commences, in the opinion of many Welsh critics, the "golden age" of their poetry, which lasts for about a hundred and fifty years, nearly to the extinction of the independence of Wales by the conquest of Edward I. After the 6th century there had been a long interval of all but silence to the 12th. The 'Myvyrian Archaiology' contains the poems of fifty-nine bards, from the time of Meilyr, who flourished between 1120 and 1160, to Tudor Ddalt, between 1340 and 1380; but it must be remarked that the dates of many of these are very unsettled, and that Mr. Stephens of Merthyr-Tydvil, in his work on the 'Literature of the Cymry,' especially devoted to this era, has rectified many oversights on this point committed by Owen Pughe and others. The first bard on the list is Meilyr, whose early poems are very inferior to his later ones, and whose finest is undoubtedly that entitled 'The Death-Bed of the Bard.' His son, Gwalchmai ab Meilyr (1150–90), who was a much superior poet to his father, is reported to have accompanied Richard Cœur de Lion to the Crusades. Fourteen compositions by him are still extant, one of which, in praise of Owen Gwynedd, on the occasion of the battle of Tal-y-Voel, in 1158 is the original of the imitation by Gray :—

"Owen's praise demands my song."

The "Awen," as the Welsh term poetical genius, seems to have been hereditary in this family, for Einion, the son of Gwalchmai (1170-1220), was also a bard, but rather to be compared to his grandfather than his father. Forty pieces by Cynddelw (1150-1200), a contemporary of Gwalchmai, are printed in the 'Myvyrian Archaiology,' of which the most interesting is his poem 'The Death-Bed of Cynddelw.' Some of his verses are addressed to the famous Madog, or Madoc, prince of Powys, one of the sons of Owain Gwynedd, and maintained by many Welsh writers to have been a discoverer of America before Columbus. Some verses of another bard, Llywarch ab Llewellyn (1160-1220), are an invocation composed by him when subjected to the fiery ordeal to ascertain if he possessed any knowledge of the fate of Madoc, whose absence seems, before it was known that he had gone on a voyage, to have been attributed to murder. One of the bards of that period was Madoc's brother, Hywel (1140-1169 or 1172), whose poems are chiefly love-odes, but who fell in a fierce struggle to obtain his father's throne. Another princely bard, and the most gifted of all the competitors of Gwalchmai, was Owain Cyveilioc (1150-97), whose poem of the 'Hirlas,' or the 'Long Blue Horn,' has been much admired by foreign critics since its first introduction to their notice in Evans's 'Specimens of the Bards.' The thought on which it is founded is very pleasing :—Owain supposes himself to be directing the horn to be 'offered in succession to his warrior-friends at a banquet, and, as it passes, he describes the character of each; but forgetting himself on one occasion, he names the name of a chief who had fallen in battle, and then a burst of grief as the remembrance comes across him preludes a warmer eulogy than usual. The names of Elidyr Sais, or

Elidyr the Saxon (1160-1220), of Philip Brydydd (1200-50), and Prydydd Bychan (1210-60), are three of the most conspicuous of the period they belong to. Their poems are chiefly eulogies on the princes and great men with whom they were connected.

The next generation of bards was that which witnessed the conquest of Wales by the English. According to a current story which has been made universally known by 'The Bard' of Gray, they must have perished by the sword of the invader; but the notion of the massacre of the bards appears to rest on no adequate authority. There is no memorial or tradition of it in the country which is said to have been its scene, and no allusion to it in the productions of bards of the time immediately following. In the 'Myvyrian Archaiology' there appears no greater falling off in the number of poetical productions than might naturally be expected as the result of a foreign conquest, of however mild a character; and the next century was destined to produce a bard who in national popularity surpassed all who preceded him.

The representatives of the Scandinavian Scalds in Cambrian poetry gave way to a Troubadour. Davydd ab Gwilym has sometimes been called the Welsh Ovid, and sometimes the Welsh Petrarch, but is said by his English translator to "approach more nearly to Burns than to any other poet, whether of his own or other countries." His poems are of a character almost entirely new in the literature of Wales; the subjects of them are chiefly themes of love and social festivity, instead of valour and heroism. The exact dates of Davydd's birth and death are unknown, but he is supposed to have been born about 1340, and to have died about 1400, the year of the death of our Chaucer. The incidents of his life, which have been related at some length by Owen Jones and Owen Pughe, are chiefly connected with his success in love and in satire. On one occasion he eloped with a married woman who had been his paramour; but the fugitives were overtaken and separated, and Davydd was condemned to pay a heavy fine, from which the men of Glamorgan, who had elected him their chief bard, and who looked more to his genius than his morality, released him by discharging it. In satire his powers were so tremendous that when Rhys Meigan, another bard, incensed him by a poem reflecting on the illegitimacy of his birth, he replied in another of such pungency that Rhys, on hearing it recited, fell down and expired. Later in life another contest of satire with Gruffydd Gryg, an ancient bard of Anglesea, was brought to a more agreeable close by a good-natured stratagem of Bola Bauol, a mutual friend. He contrived that a report of the death of each should reach the ears of the other; and, as he expected, on receipt of the sad intelligence animosity was forgotten. Davydd composed a panegyrical elegy on Gruffydd, and Gruffydd one on Davydd; and when the trick was discovered the friendship was renewed with more warmth than ever. The chief object of his satire was, however, the "Little Hunchback," Bwa Bach, the husband of the Morvydd, to whom a hundred and forty of the love-poems of Ab Gwilym are addressed. The religious orders of the time are also taken to task by a poet whose right to criticise them is not very clearly made out. Towards the close of his life, Davydd ab Gwilym, surviving his friends, became of a melancholy and religious turn, and some verses composed on his death-bed are said to breathe a strain of genuine piety.

The poems of Davydd ab Gwilym were first published in Welsh only, with an English biographical notice, by Owen Jones and Owen Pughe, in 1789. An English translation of several of the best, by Mr. Arthur Johnes, under the assumed name of Maelog, appeared in 1834. Mr. Borrow gives us to understand in his 'Lavengro' that he has completed a translation of the works of Ab Gwilym with notes, critical, historical, and explanatory, but nothing of this version has been made public. Mr. Borrow is a warm admirer of the Welsh poet. "I have no hesitation in saying," he observes, "that he makes one of the some half-dozen really great poets whose verses, in whatever language they write, exist at the present day and are more or less known."

Contemporary with Davydd ab Gwilym during the whole course of his career, and flourishing long before and after it, was Iolo Goch, the friend and domestic bard of Owain Glyndwr, or Owen Glendower, who wrote verses on the death of Tudyr ab Gronw in 1315, and on the comet of 1402, and who died about 1420, at the age, it is supposed, of nearly a century and a quarter. If the dates be correct, he must have been about 118 at the time that he spoke of Owain, who died at 67, as "old." One of his most interesting pieces, composed two years before the insurrection of Glyndwr, is a description of Owain's house at Sycharth, which the poet somewhat hyperbolically compares to Westminster Abbey, and which he describes its master as keeping almost literally an "open house," there being neither bolts, bars, nor door-keeper. Iolo Goch wrote several poems to inflame his countrymen in their rising, and lamented the death of Owain in a patriotic elegy.

Some uncertainty seems to prevail as to the date of Sion Cent, or John of Kent, a poet and religious writer, who is stated by Owen Pughe to have lived between 1410 and 1470, and by Williams to have flourished from 1380 to 1410. The latter date is probably the correct one, if Sion Cent was, as he appears to have been, a Lollard. His name was derived not from the county of Kent, but from Kentchurch, or Kentchester, in Herefordshire, where he resided. His poems, which are of interest in an historical point of view, as illustrating, like our Piers Plowman, the dawn of the Reformation, are the subject of a series of articles in the 'Cambrian Journal' for 1860. His name is

still current in popular tradition as that of a conjuror, probably owin to his having been a heretic.

The last of our list of bards of the second period of Welsh poetry Lewis Glyn Cothi, who flourished during the wars of the Roses, whic terminated in the accession of a Tudor to the English throne. He wa the bard to Jasper, earl of Pembroke, son of Owen Tudor and th widow of Henry V., and fought with his patron at the battle c Mortimer's Cross in 1461. His works are of less poetical than hist rical value, throwing a considerable light on the history of Wales durin his period. They were first published, in the original Welsh, wit English notes, chiefly of explanatory historical matter, by the Cymmrodorion, or Royal Cambrian Institution, in the year 1837, under th editorship of the Rev. John Jones, of Christchurch, known by th name of Tegid.

The bards we have mentioned are but a small proportion of thos who flourished, and some of whose compositions have been preserved. Mr. Stephens, in his 'Literature of the Kymry during the Twelfth and Two Succeeding Centuries,' mentions six-and-twenty poets whose names we have not enumerated, between 1350 and 1400; and at or subsequent to the year 1400, during the revolt of Glyndwr and the wars of the Roses, the bards amounted, he states, to "several hundreds."

It is stated by Owen Pughe, in the 'Archæologia' (vol. xiv., p. 216, that the principal heads under which ancient Welsh literature may be classed are—poetry, bardic institutes, laws, history, theology, ethics, proverbs, dramatic tales, and grammars; and that "the first of these classes, poetry, is by far the most extensive, for it may be computed to fill about eight parts out of the ten of our old writings, omitting to take into account the heraldic collections altogether; but with respect to the quantity that is printed, such a proportion may be reversed." "On this subject," he adds, "I have made a calculation so as to enable me to infer that I have perused upwards of 13,000 poetical pieces of various denominations for the purpose of collecting words in the course of about eighteen years that I have been compiling the dictionary of the Welsh language."

Towards the conclusion of the second period of Welsh literature some alterations of consequence took place in the laws of metrical composition. Certain changes appear to have been proposed and adopted at a congress of bards held in 1350, under the presidency of Ivor Hael, or Ivor the Generous, the constant patron and friend of Davydd ab Gwilym; but it was a hundred and one years later, in 1451, that at the Eisteddvod of Caermarthen, held under the influence of Gruffydd ab Nicolas, a powerful nobleman, a system was adopted which prevailed for nearly four hundred succeeding years. Davydd ab Edmwnd, a bard now of no great note, who was president of the Eisteddvod, succeeded in obtaining the assent of his colleagues to four-and-twenty new canons of poetry, which he had compiled with the assistance of other bards of North Wales, and though the men of Glamorgan protested against the decision, their protest seems to have had but little effect.

The most prominent feature in the new canons is the more definite establishment of laws of "Cynghanedd," or consonancy—a species of alliteration which was thenceforth considered as essential to verse as metre and rhyme. It had much analogy to the alliteration employed in Anglo-Saxon, Icelandic, and occasionally in earlier English poetry; but while other nations became more lax in applying it, the Welsh became more stringent. A specimen of English verse, composed about the middle of the 15th century, by a Welsh student at Oxford, to exhibit the advantages of the "cross consonancy," is printed in the second volume of the 'Cambrian Register.' A more recent example, given in Walters's 'Dissertation on the Welsh Language,' will perhaps convey a clearer notion of it than a lengthened description. The lines are on Envy:—

> "A fiend in Phœbus' fane he found,
> That yonder grew yet underground,
> Sprung from the spawn of Spite;
> The Elf his spleen durst not display,
> Nor act the devil in the day,
> But at the noon of night."

A happier instance occurs in a song by John Parry, the Welsh song-writer and composer, known as 'Bardd Alaw:'—

> "God grant that Great Britain for ever may be
> The terror of tyrants, the friend of the free."

Alliteration is appropriately introduced by Gray in the first line of his Bard:—

> "Ruin seize thee, ruthless king,"

and by Mason in his Caractacus:—

> "I marked his mail, I marked his shield,
> I spied the sparkling of his spear,
> I saw his giant arm the falchion wield,
> Wide waved the bickering blade and fired the angry air."

The lines of Mason also exemplify how easily the search after this ornament may lead to the neglect of the much more essential beauty of appropriate diction. A spear would not have been "spied," nor would a blade have "bickered," but for the attraction of alliteration. In the third stage of Welsh literature on which we are now about to enter, it was a frequent complaint that in poetry the sense was almost constantly sacrificed to the sound; but the legal restrictions on Welsh freedom in poetry could apparently only be legally removed. The laws of the Eisteddvod of Caermarthen, in 1451, were at last repealed by an Eisteddvod of Caermarthen, in 1819, and Welsh poetry has materially benefited by this Reform Act.

Third Period—1536-1760. The next period of Welsh literature commences with the Reformation and with the incorporation of Wales with England by the Act of Parliament of King Henry VIII., in 1536, two events which changed both the religious and the political aspect of the country. In Wales the Reformation, introduced by a Tudor monarch, took from the first a much firmer root than in other Celtic countries; but there, as elsewhere, some of the learned adhered to the ancient faith, and in the reigns of the early Protestant sovereigns were compelled to carry their dissent abroad.

The first book printed in the Welsh language, which was also the first book printed in any Celtic language, was a species of Almanac, by William Salesbury, with a translation of the Lord's Prayer, the Ten Commandments, &c., issued at London in 1546, in a quarto volume. Salesbury, who was an eminently learned man and the master of nine languages, was a master also of his mother-tongue. He published the first Dictionary of English and Welsh, in 1547. He wrote on orthography and kindred subjects, and appears to have had it at heart to make both the Welsh and English nations better acquainted with each other. He was also a zealous Protestant, and wrote the greater part of the first translation of the New Testament into Welsh—a translation so excellent that it forms the groundwork of that still in use. It was first published at London, in 1567, in a quarto volume, a copy of which is one of the choicest treasures in Welsh libraries.

The history of the Welsh translation of the Bible is curious. In the year 1562 or 1563 it was enacted by Parliament that "the Bible, Testament, and Common Prayer should be translated into the British or Welsh tongue; should be viewed, perused, and allowed by the bishops of St. Asaph, Bangor, St. David's, Llandaff, and Hereford; and should be printed and used in the churches by the 1st of March in the year 1566, under a penalty in case of failure of forty pounds on each of the bishops." Salesbury was engaged by the bishops to carry out this important commission; his friend Dr. Richard Davies, bishop of St. David's, assisted him by translating a portion; and in 1567, a year after the term fixed by the Act of Parliament, the Testament made its appearance. After this came a long pause. Salesbury was residing, for the purpose of carrying on the translation, with the Bishop of St. David's, when a dispute arose between them on the meaning and etymology of one word, and ran to such a length that the two friends parted for ever. The consequence of this not very Christian outbreak was, that the Welsh were left without a Bible for more than twenty years. The penalty provided by the Act was too small to enforce it; for the bishops, who seem to have had to defray the expense of the translation, would have had to pay more than the forfeit to carry it out. In 1588 the difficulty was solved by the appearance at London of a translation executed by Dr. William Morgan, vicar of Llanrhaiadr, in Denbighshire, not in consequence of the Act of Parliament, but because he felt the necessity of the work for his countrymen. Morgan received a bishopric in recompense: he was promoted in 1595 to the see of Llandaff, and "translated," says Llewellyn, the historian of the Welsh Bible, "to St. Asaph in 1601, and in 1604 to a better place." His successor at St. Asaph, Dr. Parry, published in 1620 a revised edition of this Bible, with considerable alterations; and in the Scriptures of both editions, Salesbury's translation of 1567 affords the groundwork of the Testament. The Welsh have, like the English, been remarkably fortunate in their translation of the Bible. It is with both nations the acknowledged standard of the language, and equally a favourite with the learned and the people. It is now in Wales the book of every household; but this state of affairs has only been attained by degrees. In Prichard's 'Canwyll y Cymry,' the date of which is that of the triumph of English Puritanism in the time of the Commonwealth, are some lines thus translated by Evans:—

> "Women and men of low degree,
> The very abjects of the land,
> You always may in England see
> Each with the Bible in his hand.
>
> "With us, 'mongst those who most abound,
> And sumptuously their tables spread,
> Scarce can a prayer-book be found,
> Or one who can his Bible read.
>
> "'Tis to the Welsh a foul disgrace
> They're in religion still so young,
> That not a tithe of all the race
> The Scriptures read in their own tongue."

In 1802 Owen Pughe stated that nineteen editions of the Bible, amounting to upwards of 130,000 copies, had circulated in Wales; and yet it was the demand for more copies at that very time which led the Rev. Thomas Charles, of Bala, to propose the establishment of a benevolent religious society for printing and distributing Bibles in Wales—a notion which expanded and developed under the guidance of Welshmen till it led to the foundation of the great British and Foreign Bible Society. One of the first publications which the Society took in hand was naturally the issue of the Welsh Bible; and a vivacious account is given in the 'Christian Observer,' by an eye-witness, of its reception in Wales:—"When the arrival of the cart was announced which carried the first sacred load, the Welsh peasants went out in crowds to meet it, welcomed it as the Israelites did the Ark of old, drew it into the town, and eagerly bore off every copy as rapidly as they could be distributed. Labourers carried it with them to the fields, &c." The number of copies issued by the Bible Society in Wales between 1806 and 1849 was, of Bibles, 329,131, and Testaments, 384,209, while of "Diglotts, Welsh and English, there were 1986."

While the Protestant Salesbury had the honour of publishing the first Welsh book in England, a zealous Catholic, Dr. Griffith Roberts, issued the first that was printed abroad, both of them anticipating by more than a century and a half the first Welsh book printed in Wales. In the celebrated letter addressed by Dr. Johnson to the King's Librarian on the purchase of books during a foreign tour, he made the remark: "In every place things often occur where they are least expected. I was shown a Welsh grammar, written in Welsh and printed at Milan, I believe, before any grammar of that language had been printed here." The book which had attracted Dr. Johnson's observation was only the first part of a treatise on grammar, 'Dosparth byrr ar y rhan gyntaf i Ramadeg'—a treatise on orthography embodying suggestions of some value for the improvement of the Welsh alphabet, illustrated with peculiar types. The volume bears the date of 1567, but no indication of its place of imprint; and the authority for the usual assertion on that score was that David Rhys, in the Latin preface to his 'Cambro-Britannicæ Linguæ Institutiones,' said that the book of his predecessor was printed at "Mediolanum." A few years ago the old tradition on the subject was combated by the ingenious argument that as there is more than one place in Wales itself the name of which is Latinised into Mediolanum, the book might have been printed at, for instance, Llanvyllin. Unluckily for the new view, a decisive confirmation of the old one has since been discovered in another book, by Griffith Roberts, a religious treatise entitled the 'Drych,' or 'Mirror,' containing a fervent exhortation to his countrymen in behalf of the Roman Catholic faith. In this book, which was printed at Rouen about 1585, the exhortation is signed "G. R.," and dated "O Fulan" ("From Milan"); while in a preface by Dr. Roger Smith the author is styled "the great teacher of the city of Milan, in the land of Italy" ("yr Athro mawr o Dhinas Fulan yngwlad yr Idal"), where it is moreover added that some of his books have been printed. Griffith Roberts also left behind him some imperfect books on grammar, which he had commenced to print, but never completed, and of which it is said that only three copies are at present known: that presented by the Welsh School, formerly of Gray's Inn Lane, to the British Museum; that in the library of Wynnstay, which fortunately escaped the conflagration of 1858; and that in the library of Mr. Wynne of Peniarth. The works of Roberts are well deserving of republication.

Another Welsh scholar who spent some time in Italy, but who returned to die in a cottage in Breconshire, was Dr. John David Rhys, already mentioned. He left the University of Oxford in 1555 without taking a degree, and resided for some time at Sienna and Padua, where he practised as a doctor of physic, and published a book in Italian on the study of Latin, and a book in Latin on the pronunciation of Italian. His principal work is his grammar of Welsh, 'Cambrobrytannicæ Cymrææcæve Linguæ Institutiones et Rudimenta,' in which he enters at great length and with much learning on the subject of Cambrian prosody, on which he is still consulted. The book was published in London in 1592, at the expense of Sir Edward Stradling, of St. Donat's Castle, a munificent patron of Welsh literature, and a cousin of that Sir Edward who was so near losing his life on suspicion of being a Saxon. Rhys, who was born in 1534 in Anglesey, died in 1609 in Brecon, and is said by Anthony a Wood to have died as he had lived, a Roman Catholic; but in the title page to his 'Institutiones' he lays especial claim to the merit of facilitating the study of the Holy Scriptures, "lately so elegantly and chastely translated into Welsh," a circumstance which, with some others, favours the supposition of his having become a Protestant.

One of Rhys's friends, to whom he refers in his works as an excellent genealogist and antiquary, was Thomas Jones, of Tregaron, or Twm Sion Catti, whose remarkable career has already been noticed in connection with his transcript of the 'Triads.' Jones was a poet as well as an antiquary, but while his reputation as a robber and magician still survives, that as a poet has passed into oblivion. He died about 1620.

A metrical version of the Psalms, which was written about this period, is still in high esteem. It was produced by a captain in Queen Elizabeth's fleet—William Myddelton, the elder brother of Sir Hugh Myddelton, the projector of the New River, and himself remarked for having been one of the first three who smoked tobacco in England, when crowds gathered round to witness the phenomenon. He did warlike service in America and the Azores, and records in a Latin note to his last Welsh Psalm that he finished it on the 24th of January, 1595, at "Scutum," one of the West Indian Islands. The Psalms, which appeared in 1603, were a posthumous publication, but Captain Myddelton had issued in his lifetime, in 1593, the first part of a treatise on the art of Welsh versification, 'Barddoniaeth,' which was never completed. The Psalms were reprinted in 1827.

The most popular poem, not only of that period, but of any period in the history of Welsh literature, was produced, it is said, by the simple process of turning into verse a series of sermons. The Rev. Rees Prichard, known as the Vicar of Llandovery, was as popular a preacher in his lifetime as after his death he became a popular poet. When he preached at St. David's the cathedral was too small to hold his congregation, and he was cited in the ecclesiastical courts for having set up a movable pulpit in the churchyard. Perceiving the partiality of his flock for verse he turned his homilies into rhymes, and the collection was first published in 1646—two years after his death. "The work," says Williams, in his 'Lives of Eminent Welshmen,' "was no sooner printed than it appeared in almost every hand, and was heard from almost every mouth throughout the principality, and it is scarcely credible with what uncommon avidity and pleasure it was received, read, and repeated by the people." The Italian student is reminded by this account of the passage in Bernardo Tasso's letters, in which he speaks of the first appearance of Ariosto's epic and its overwhelming success. The secret of the popularity of Prichard's volume, the 'Canwyll y Cymry,' or 'Candle of the Cambrians,' as it is called, appears to have lain in its combined religious and homely character—it did not fly one inch above common apprehension. A passage has been already quoted from an English translation of it by the Rev. William Evans, which was published in 1771, and this passage may be taken as an average specimen. The 'Candle of the Cambrians' is not yet extinguished, for the last edition, about the twentieth, appeared with notes, &c., in 1858. Its author was born at Llandovery in 1579, became vicar of the parish in 1602, and died at Llandovery in 1644, and the two last and best editions of his work are from the Llandovery press.

The next bard who deserves attention in a general survey of Welsh literature is Huw Morus, or Hugh Morris, who was born in 1622, and survived till 1709. "He is to be ranked," we are told in the 'Cambrian Register,' "among the first of the Welsh poets. He eminently excelled in that talent which we call humour, and was equally master of the pathetic and the sublime." The same writer states that his 'Elegy on the Death of Mrs. Middleton,' is equal or superior to "the two most beautiful compositions in the English language on the same subject, the 'Monody' on the death of his lady, by Lord Lyttelton, and that 'To the Memory of a Young Lady,' by Mr. Shaw." The works of Huw Morus were published in two duodecimo volumes, at Wrexham, in 1823, under the title of 'Eos Ceiriog,' or 'The Nightingale of Ceiriog.'

The most distinguished bard of the 18th century was Goronwy Owen, who is styled by Owen Pughe "one of the greatest poets that appeared among the Welsh." He was the son of a peasant in Anglesey, where he was born on the 1st of January, 1722, and was indebted for his education to Mr. Lewis Morris, a distinguished antiquary, who had him brought up for the church. He married in Oswestry, where he was curate, and says in one of his letters, "My wife speaks very little Welsh, yet she understands some; so that I fear that if I go not to Wales, my boys will be Saxons, for by the life of me I cannot teach the eldest one word of Welsh." He was curate to Dr. Douglas, afterwards bishop of Salisbury, "the person," he says, in one of his letters, "who defended the poet Milton against the insidious defamation of Lauder. Be it as it may, he is sufficiently severe and hard towards me. I hold some little land of him appertaining to the school, and though it was set too high before, yet he has sent down this year orders to raise the rent, lest a poor wretched curate should gain anything in his service, or obtain too good a bargain at his hand." His career appears to have been a very unfortunate one; but it must not be forgotten that he was an incorrigible drunkard. His poverty led him to petition the Cymmrodorion Society, in 1757, for assistance towards paying his passage for America, where he settled at Williamsburg in Virginia; and after the year 1767 nothing further was heard of him. "About the year 1798," says Owen Pughe, in the 'Cambrian Biography,' "some persons who revered his memory tried to obtain information if he were alive or dead, and with that view sent a letter over to his son. Him they found perfectly Americanised; before any answer was sent, he must first know who would pay him for his trouble." In a life of Goronwy Owen by Mr. Borrow, first printed in the 'Quarterly Review' for 1861, it is stated that he died about 1780. The principal poems of Goronwy Owen are to be found in the first volume of a book called 'Diddanwch Teuluaidd,' or 'Domestic Amusement,' printed at London in 1763. In a curious preface the printer states that the work was 'put into his hands by the editor, Hugh Jones,' who "owned himself incapable of writing an English preface to it, and therefore desired me to do that office for him." "The editor," he adds, "being an itinerary bard in the manner of the ancients, hath given me leave to tell his readers that he pretends to neither learning nor languages; he despises them all except his own, as the chief Greek poets did, calling other languages barbarous. He can hardly be persuaded that the English or French nations have anything that may properly be called poetry; such is man's partiality towards his own country and people."

The prose literature of the third period is remarkably poor. Its most popular production is itself only an adaptation or imitation of a foreign original, the 'Bardd Cwsg,' or 'Sleeping Bard,' of Ellis Wynne, first published in 1703, and since frequently reprinted, the last time in 1861, with notes by Silvan Evans. It consists of a series of visions of hell and the invisible world, chiefly taken from the visions of Quevedo, the Spanish humourist, which were translated into English, and for a time enjoyed considerable popularity. Wynne had prepared a second work, 'Gweledigaeth y Nev,' or 'A Vision of Heaven,' but was so mortified at being spoken of as a plagiarist from Quevedo, that he threw the manuscript into the fire. The plan of the "Bardd Cwsg" is a singularly gloomy and repulsive one for a satire; but the beauty of the style is so striking, that the book remains popular in Welsh; and, strange to say, a translation of it into English was published in 1861 by Mr. George Borrow, the author of 'The Gipsies,' and 'The Bible in Spain.' Ellis Wynne also translated into Welsh, Jeremy Taylor's 'Holy Living,' and revised the version of the Common Prayer, and though most celebrated for his prose, enjoyed some reputation as a poet. He was induced to take holy orders, though he had no inclination for the ministry, and held the rectory of Llanvair. He was born in 1670 and died in 1734.

A vigorous attempt to call attention to the study of the ancient literature was made towards the end of this period by the Rev. Moses Williams, an antiquary and author, who was in advance of his age, and has not yet received his due share of fame. There are in the British Museum printed 'Proposals for printing by subscription a Collection of Writings in the Welsh Tongue to the beginning of the Sixteenth Century,' dated July 31st, 1719. "This design," it is said, "hath been approved of by such gentlemen as have been made acquainted therewith, who have promised to encourage it as well by subscribing to it as by communicating their manuscripts, some whereof are already put into the publisher's hands. . . . Subscriptions for the first volume are taken in by Mr. Alban Thomas, at the Royal Society's House in Crane Court, Fleet Street; Messrs. William and John Innys, booksellers in St. Paul's Churchyard, London; and by the editor, Moses Williams." A specimen is subjoined of two pages of the 'Liber Triadum,' or Book of Triads, in Welsh only. Bound up in the same volume with it in the Museum is a manuscript portion of the intended preface, in Latin, apologising for publishing the documents in the original language without a translation, which is excused on the ground of the extreme difficulty of arriving at a certain knowledge of the meaning of every sentence in the then state of the study of the language. The writer, Moses Williams, was, however, at that time one of the best Welsh scholars living, and the glossary which he supplied to Wotton's 'Leges Wallicæ' is a proof of his erudition. The library of the Earl of Macclesfield contains a number of transcripts which he had made, doubtless for the purposes of this intended work, and which are likely to be of great critical value. Had his proposals been received with favour, he might have had the glory of anticipating the 'Myvyrian Archaiology.' Williams was a singularly diligent and accurate scholar, and published a 'Repertorium Poeticum,' or list of Welsh poems, and a general catalogue of Welsh books, which will be mentioned more particularly hereafter. Two Welsh sermons, preached and printed by him in London, in 1717 and 1719, are in the British Museum, and are of considerable interest from the information they contain on the state of the Welsh church, and of the Welsh language at that period. They are not mentioned, so far as we are aware, in any of the notices on Williams's biography, of which the most ample that we have seen is in Williams of Llangadwaladr's 'Lives of Eminent Welshmen.' He was born in Cardiganshire in 1685, and died as vicar of St. Mary's, Bridgewater, in 1742.

It has been mentioned that the early editions of the Welsh Bible were printed in London, and the introduction of typography into the Principality was exceedingly slow. Cotton, in the 'Typographical Gazetteer,' states that the earliest information he possesses on the subject is from one of the Martin Mar-Prelate tracts in Queen Elizabeth's reign, in which mention is made of 'knave Thackwell the printer, which printed popyshe and traiterous Welshe books in Wales,' and nothing more has ever been discovered of the printer or his books. Penry, who was hanged as the author of the Mar-Prelate tracts, was by birth a Welshman. In the 'Gentleman's Magazine' for August, 1821, it is observed by a correspondent, that "from the invention of printing downwards, so adverse were the circumstances attending the diffusion of Welsh literature, that there was not a printing-press in the principality until the year 1734, or thereabouts, when a temporary one was set up by Mr. Lewis Morris, of Bod-Edeyrn, in Anglesey. This identical press," the correspondent adds, "is still in being at Trevriw, near Llanrwst."

Fourth Period—1760-1861. A new period in the history of Welsh literature may be said to commence with the reign of George III., a hundred years ago, soon after the middle of the 18th century. The remarkable increase of activity which is observable in that literature during these hundred years, and especially during the last forty, seems to be attributable to the spontaneous impulse given by a few distinguished men; to the spread of Methodism in Wales; to the establishment, for the first time, of periodical publications; and to the institution or revival of patriotic societies.

One of the first signs of a new era in the literature of Wales was given by the publication in 1764 of a thin but important quarto volume. "Some Specimens of the Poetry of the ancient Welsh Bards translated into English, with explanatory notes on the historical passages and a short account of the men and places mentioned by the Bards, by the Rev. Mr. Evan Evans, curate of Llanvair Talyhaern, in Denbighshire," (London, 1764). It was the first book in which the claims of the Welsh bards were brought under the notice of the English public. Evans says in his preface that it "was first thought of and encouraged some years before the name of Ossian was heard of in England," but it was evidently the success of Macpherson's Ossian which had brought the project to maturity. "Certainly," says the author in a Welsh address to Mr. Richard Morris, printed in the volume, "I would not have taken this labour upon me except to put a stop to the reproaches of the English, who say that we have nothing of poetry to show the world, while one of the Scotch Highlanders has translated portions of their ancient bard, or rather has dressed up and adorned some recent production and put it forth in his name." He is not sparing of his insinuations against the genuineness of Ossian, and his critical remarks on the ancient bards of Wales are marked by acuteness. His greatest mistake is that he does not question the truth of the massacre of the bards, of which he remarks that it "gave occasion to a very fine ode by Mr. Grey." ‘Evans's own prose translation of pieces by Gwalchmai and others also gave occasion to some imitations by Gray, which, though of no great merit, are of all translations from the Welsh by far the most extensively known. His volume concludes with an excellent proposal to send a literary traveller through Wales to examine and transcribe the remains of ancient poetry; but it appears to have met with cold neglect. Evan Evans was born in 1731, and died in 1789. He entered the church, but rose to no higher position than that of a curate in a parish said to derive its name from the ancient bard, Talhaiarn, and which also gave birth to the living bard, Talhaiarn. As a Welsh poet his reputation is now even higher than during his lifetime. Theophilus Jones, the historian of Brecknockshire, says in a letter written in 1797, "I did not think Evan Prydydd Hir (the bardic name of Evans) the poet he was. I knew him well, but I suppose the *cwrw* had expelled the *awen* before I became acquainted with him." Despair appears to have driven the disappointed man of talent to drink, and at the time of his death, in 1789, he was reported to have perished in a state of intoxication on a mountain, a report which happily appears to be unfounded. He left behind him a good collection of transcribed manuscripts, which passed on his death to Mr. Panton, of Anglesey, who had allowed him an annuity on that condition. Two volumes of Welsh sermons published by him contained an English preface so caustic as to be said to have stood in the way of his preferment.

Of the distinguished men of this period none seems to have acted more entirely from internal impulse and to have had a stronger influence on others than Owen Jones. Owen Jones was born at Llanvihangel Glyn y Myvyr, in Denbighshire, in 1741. "In early life," says the Rev. Robert Williams, "he was sent to London, where he was taken into the employ of Messrs. Kidney and Nutt, furriers in Thames Street, to whose business he eventually succeeded, and he continued to carry it on with credit until his decease," which took place at his house in Thames Street, in 1814, at the age of seventy-three. Count Villemarqué, in the preface to his translation of the ancient bards, gives a very poetical sketch of the biography of Owen Jones. "While still a child," he says, "and engaged in herding cows, he could see at a distance rising through the air the snow-covered peak of Snowdon, the Celtic Parnassus, on whose summit whoever slumbers awakes inspired. He ascended it more than once, and his happy inspiration might make us believe that there he must have slept. When he was older, he often witnessed on this mountain the poetical contests of the bards and harpers of the different cantons of the country, and passing at the foot of the ancient castles which held the poetic treasures of his race he formed the daring project of bringing them to the knowledge of the world."

There are here some palpable mistakes, as in attributing to Snowdon the properties of Cader Idris, on whose summit it is the popular belief that whoever sleeps awakes either crazy or a poet, and it is not probable that Snowdon was often ascended by a Denbighshire boy. But however hyperbolically expressed, the sentiment is correct. In the midst of his prosperous business in London, Owen Jones was still a warm-hearted Welshman, far more munificent in the promotion of his country's literature than all the magnates of the country combined. In 1771 he founded the society of Gwyneddigion (or Men of Gwynedd, a portion of North Wales), which revived in a manner the ancient congresses of the bards, and distributed prizes among the best performers on the Welsh harp and the writers of the best Welsh poems. In 1789 he published with Owen Pughe the poems of Ab Gwilym, and in 1801 and the subsequent years up to 1807 he issued at his expense three volumes of the ‘Myvyrian Archaiology,’ so called in his honour from Myvyr, the bardic name which he had assumed in remembrance of his native vale of Myvyr, in Denbighshire. Owen Pughe and Edward Williams were, as has been already mentioned, the editors of the work. The chief connection of Jones with the Archaiology was in supplying the funds, and it is said that he thus expended upwards of 1000*l.*—a sum, large as it was, by which he cheaply earned the gratitude and respect of all lovers of literature of his own times and all to come. His last literary enterprise was the publication of a periodical, ‘Y Greal,’ which appeared in 1805 and advanced no further than one volume. In this too, Owen Pughe was the editor and Owen Jones only the Mæcenas. The triad of his labours was thus formed by the Gwyneddigion Society, the ‘Myvyrian Archaiology,’ and the ‘Greal.’

William Owen or William Owen Pughe, as he was called in later life after he had inherited some property in Wales, was an antiquary, a lexicographer, and a poet. He was born in 1759, in a primitive part of Merionethshire, close to Cader Idris, from which he assumed the bardic name of Idrison, and he closed a long life in 1835, at the foot of the same mountain, to the vicinity of which he happened to be on a visit. Till he was seven years old he heard not a word of English, and though he went to school at Altringham, near Manchester, and at the age of seventeen was sent up to London to earn his living, he never seems to have acquired a thorough mastery of the English language. His English has always a taint of Welsh in it, while, on the other hand, his colleague, Edward Williams, says that his Welsh writings "may be said to be English written in Welsh words." In the great city he remained for six years without knowing that any other person in it ever thought of the Welsh language and literature, till an accidental meeting with another Welshman, who introduced him to Owen Jones, brought into connection two men who scarcely seem to have passed a day without doing something for both. The largest Welsh and English dictionary in existence, published in two large volumes between 1793 and 1803, was the work of eighteen years of Owen Pughe's life. It is said in regard to it, by the Rev. R. Williams, that "while Johnson's Dictionary of English, as enlarged by Todd, comprises only 58,000 words and Webster's about 70,000, Owen Pughe's Dictionary of Welsh contains more than 100,000 words, illustrated by 12,000 quotations." The dictionary would be much improved by striking out many of these words which appear to exist only in its pages. In it Owen introduced a new system of Welsh orthography, and his friend, the Rev. T. Charles, of Bala, who was appointed at the same time to superintend through the press the edition of the Welsh Bible, the agitation for which had given rise to the British and Foreign Bible Society, took the opportunity of introducing it there; but the Society interfered and the system was obliged to be dropped. In the second edition of his dictionary, issued at Denbigh, in 1832, the customary spelling is used. There is an abridgment of the work by Owen himself in 1806, which is much too compendious. In 1806 Owen came into possession of some property by inheritance, which enabled him to take up his residence in Wales, at Tros-y-Parc, near Denbigh, and to have the command of his time, which he devoted as usual to Welsh literature. His most important work of this period is a translation of ‘Paradise Lost’ into Welsh, which has a peculiar importance from his having thrown off in it the shackles of "Cynghanedd" or alliteration, which had fettered the movements of Welsh poetry for centuries. The innovation was a most happy one: it was adopted by the Eisteddvod of Caermarthen in the same year, and has been followed by many succeeding bards with great advantage. Owen Pughe was known to Southey the poet, and is frequently mentioned in his correspondence, but not always in terms of respect. On one occasion Southey expresses his surprise that Pughe should have translated ‘Paradise Lost,’ of which, in Southey's opinion, he could hardly understand a sentence; and on another Southey says of him, in a letter to Wynne, "full of Welsh information he certainly was, but a muddier-minded man I never met with." That there was some foundation for this opinion may be inferred from the fact that Pughe was a follower of Joanna Southcott, and was one of her twenty-four elders. Edward Williams, who quarrelled with him in the latter part of his life, said in a letter, in 1813, that Owen "with his *hobbyhorsisms* absolutely ruined everything he ever took in hand."

Edward Williams, still better known by his bardic name of Iolo Morganwg, is the third of the three associates of the "Myvyrian Archaiology," and undoubtedly the most gifted of the three. Less fortunate than his companions, he was born in so low a sphere of life that at the age of nine he began to assist his father at his trade of a stonemason, and with all his endowments he worked through life at the trade, though never in strong health, and in his old age was in need of the assistance of a public subscription. He was born in 1745, in the parish of Llancarvan, in Glamorganshire, and was noted in youth for absence of mind and literary enthusiasm. On a quarrel with his father he left him abruptly for London, and worked as a stonemason at Blackfriars Bridge. An interview which he sought with Dr. Johnson in a bookseller's shop only left a painful impression of the great lexicographer's rudeness; and though he saw Cowper, the poet, he only saw him in his decline. With Robert Southey he appears to have been intimate, at a time when Southey, like himself, was full of republican ideas, and the English poet drew from him much of the Welsh lore of his ‘Madoc,’ and introduces him as a character in the poem under the name of Iolo. Of all English authors of celebrity, Southey took the greatest interest in Welsh history and literature; and if he had carried out his purpose of fixing his residence in the Vale of Neath, which was only prevented by a trifle, the literary consequences might have been important. He had a high opinion both of the talents and the character of Iolo. "Bard Williams is in town," he wrote once to his wife, when on a visit to London, "and so I shall shake one honest man by the hand whom I did not expect to see." Both the bards had a thorough abhorrence of the great metropolis; and Williams, who at one time proposed to emigrate to America, not, like Southey, to found a Pantisocracy, but to search for the descendants of Madoc and his men, finally returned to Flemingstone, in Glamorganshire, within about two miles of his birthplace, and there continued till his death. Iolo, like his friend, was a great pedestrian, so much so, that when his son Taliesin bought him a horse, he could not be prevailed upon to ride, and carried his eccentricity so far as to lead the animal about the country on his journeys without ever mounting it. He had a personal triad of his own: "There are three things I do not want: a horse, for I have a good pair of legs; a cellar, for I drink no beer; and a purse, for I have no money." It is painful to record that he quarrelled with his friends of the 'Myvyrian Archaiology,' and complained that Owen Jones had not paid him some money which was due to him; while at the same time his principles were so high that he refused to take possession of an estate in Jamaica, which had been left him by his brothers, because it was cultivated by slaves. He wrote between two and three thousand Welsh hymns, some of which are highly esteemed, and were published under the title of 'Salmau yr Eglwys yn yr Anialwch' ('Psalms of the Church in the Desert'); but, as his friend Waring tells us, "his creed appeared to be so whimsical a compound of Christianity and Druidism, Philosophy and Mysticism, that the 'History of all Religions,' copious as it is in variety, furnishes no definition of it." He was surrounded, in spite of his eccentricities, by general respect, which was strikingly manifested at the great Eisteddvod of Caermarthen, in 1819. His death took place in 1826, at the age of eighty-one. He appears, from some letters published in the 'Cambrian Register' for 1818, to have written his autobiography, with a survey of Welsh literature during his time, but this work, which would certainly have been of value, has disappeared. His son, Taliesin Williams, was to have written an extended biography of his father, but the project was never put in execution. A life of him, which appeared in 1850, from the pen of an English friend, Elijah Waring, who was unacquainted with the Welsh language, is an amusing volume of light reading, but not the sort of biography required; for though in all his letters and writings which remain, Iolo Morganwg appears the frankest of the frank, there are several points in his literary career which require elucidation, and on which depend important questions with regard to Welsh literature.

Edward Williams was an English as well as a Welsh poet. His 'English Poems, Lyrical and Pastoral,' published in two volumes with the date of 1794, present perhaps the most curious list of subscribers that was ever attached to any publication. It begins with the name of the Prince of Wales; it contains those of Mrs. Barbauld and Miss Burney, of William Lisle Bowles the poet, and William Bowles, "Generalissimo of the Creek nation," Miss Hannah More and Mrs. Yearsley the milkmaid, Cowper, the poet of the 'Task,' and Rogers, the poet of the 'Pleasures of Memory,' Cyril Jackson, Dean of Christ Church, and Dr. Priestley of Birmingham, Mr. Raikes of Gloucester, the founder of Sunday Schools, and Mr. Thomas Paine, Dr. Parr and Mr. Horne Tooke, Citizen Brissot, Wilberforce and General Washington. The poems are of some merit, but the chief point of interest that now attaches to the volumes centres in the notes. One of the pieces is an 'Ode on the Mythology of the Ancient British Bards in the manner of Taliesin, recited on Primrose Hill at a meeting of British Bards in the summer solstice of 1792, and ratified at the subsequent autumnal equinox and winter solstice.' Primrose Hill was then a comparatively unfrequented green height in the fields between London and Hampstead, distinguished by a grove of trees which was barbarously cut down about 1828, and being in view of Owen Pughe's residence at Pentonville, may have been selected as a more convenient place for a meeting of bards than the summit of Plinlimmon originally named. Edward Williams, who was then an ardent republican, seems to have been at the same time an equally ardent defender of the privileges of the British bards. These, he maintained, were a regular corporate body, traceable from the earliest times to his own, in which there was only one legitimate board of bards remaining, the "Chair of Glamorgan," and only two members of that, himself and the Rev. Evan Evans of Aberdare.

In the notes to his 'Ode,' he gives a number of Triads in Welsh and English, containing the doctrines of "the Bards," and embracing a system of theology which is declaredt o be anterior to Christianity, but no more adverse to it than the religion of Enoch, Noah, and Abraham. "There are three circles or states of existence," according to one of these Triads: "the Circle of Infinity, where there is nothing but God of living or dead, and none but God can traverse it; the Circle of Inchoation, where all things are by nature derived from death—this circle has been traversed by man; and the Circle of Felicity, where all things spring from life—this man shall traverse in heaven." "Animated beings have three states of existence," says another Triad; "that of Inchoation in the great deep or lowest point of existence, that of Liberty in the state of Humanity, and that of Love which is felicity in Heaven." The system is further explained as one of metempsychosis, and there is a larger development of it contributed by Williams to the preface to his friend Owen Pughe's edition of Llywarch Hen. In this it is said, among other things, "No finite beings can possibly bear the infinite tedium of eternity. They will be relieved from it by continual renovations at proper periods, by passing into new modes of existence and which will not, like death, be dreaded, but be eagerly looked for and approached with joy. Every existence will impart its peculiar epoch of knowledge, for consciousness and memory will remain, or there would be no such thing as endless life."

These doctrines, first put in print at the time of the French Revolution, certainly bear a close resemblance to many of those which had their origin at that period, and it was a point of some interest to know how far back they could in reality be traced. Williams informed his readers of his 'Poems' that the Triads he had given were "from a manuscript collection by Llewelyn Sion, a bard of Glamorgan, about the year 1560. Of this manuscript" he added, "I have a transcript; the original is in the possession of Mr. Richard Bradford, of Bettws, near Bridgend, in Glamorgan. This collection was made from various manuscripts of considerable, and some of very great, antiquity—these and their authors are mentioned, and most or all of them still extant." It is not surprising that they were not received with unlimited confidence in their authenticity, but it is very surprising that Iolo did not take the best method of silencing doubts by printing the manuscript in the Myvyrian Archaiology, which a few years after he was engaged in editing. Far from this, he did not even show it to his friend who published the extracts. The manuscript in which they were contained bore the title of 'Cyvrinach y Beirdd' or the 'Secret of the Bards,' and was in two parts. "Edward Williams had only the first part with him in London," says Owen Pughe in a letter to his son in 1819, first printed by his grandson (in the 'Cambrian Journal' for 1857, p. [illegible]) "at least he said he had not the second, which by his description is the most curious, and the real Cyvrinach," and this Owen Pughe never saw. The association of the Myvyrian Archaiology finally broke up without its appearing. "In my collection," says Iolo, in a document printed by Waring, "I strenuously opposed the absurd fables of the darker ages, which are most obviously falsehoods of the darkest hue. This gave offence to my coadjutors, who charged me with rejecting supposititious documents which never existed, which I with diligence could never find, and which they cannot but know do not exist elsewhere. Such are the fictions of Geoffrey of Monmouth, that of King Arthur and his Knights of the Round Table, and many things more of the same character." It would seem from this that Williams quarrelled with Owen Pughe on the question of the insertion of the Mabinogion, which never appeared in the Archaiology, but it is strange that under the circumstances he should talk in this strain respecting "supposititious documents." The Rev. Edward Davies, in his 'Mythology of the Druids,' published in 1809, very plainly intimated that he considered the 'Bardic Triads,' with their theophilanthropic ideas, as supposititious. Doubts on the same score were freely expressed by many, but in 1819, Iolo Morganwg had a distinguished triumph at the Eisteddvod of Caermarthen, where he invested Dr. Burgess, the Bishop of St. David's, with the insignia of a Bard. From that time Bards, Druids, and Ovates, once reduced to two in number, have become numerous and in vogue, and Bardism has held a position in Wales analogous to that of Freemasonry in England. The call naturally became louder for the publication of the documents on which the institution was supposed to rest; and finally, in 1822, Iolo Morganwg, then a man of seventy-seven, issued a prospectus to publish a work in Welsh to contain the 'Esoteric Literature of the British Bards.' He died four years after without having published it. It was only in 1829 that his son brought out the long-expected 'Cyvrinach y Beirdd,' and in it, to the surprise of all, though the work was published as complete, no 'Triads of Bardism' were to be found. The 'Cyvrinach' of 1829 was simply an excellent treatise on Welsh versification by Llewelyn Sion, of Llangewyd, interspersed with some very absurd statements respecting the Welsh language before the Flood, which of course derived no authority from having been made by a man of the age of Elizabeth. According to the 'Cyvrinach' there are but three proper languages—that spoken by Adam before the Fall, which is now the language of God, the angels, and the saints in Heaven; that written by Moses, which is the language of the Scriptures (a statement showing that the writer did not know that the Testament is in Greek); and that first spoken by Enoch, the son of Seth, and now spoken by the Welsh in Wales. Welsh is thus the only living language of divine origin; and the Awen or poetic genius of the Welsh is due to divine inspiration, while the poetry of the Saxon, English, and other corrupted languages, is inspired by their inventor—the devil.

Some disappointment was naturally felt at the non-appearance of the 'Bardic Triads' in the book, the chief interest of which consisted in its being supposed to contain them, but no explanation could be obtained further than that, of the two parts of the 'Cyvrinach,' Taliesin Williams had only printed the first. No public information was vouchsafed as to why he had not printed the second, or what had become of it. The admirers of the Bardic Triads were reduced to look forward to the publication of them in a volume on the Iolo Manuscripts, a large collection of transcripts made by Iolo Morganwg, and from which Taliesin was engaged by the Welsh Manuscript Society to make and publish a selection. By a second misfortune, Taliesin Williams died in 1847, before the publication of the Iolo Manuscripts, as his father had died before the publication of the 'Cyvrinach.' So much, however, had been printed before his decease, as to render it certain that the Bardic Triads would have formed no portion of the volume. The Iolo Manuscripts, published by the Welsh Manuscript Society in 1849, contain a variety of pieces of very different value, respecting the origin of which we only learn that they were taken from transcripts made by Iolo Morganwg from other transcripts of which he mentions the possessors, adding in some cases from what originals they were transcribed. One of these pieces, called the 'Voice Conventional of the Bards of Britain,' contains an account of the origin of the ancient Welsh alphabet at the time of the Creation, taken also from a manuscript by Llewelyn Sion of Llangewyd. But again, as has been said, the 'Bardic Triads' are missing, and in 1861 the 'Secret of the Bards' is still a secret.

Taliesin Williams appears to have told the Rev. Thomas Price, after the death of Iolo ('Cambrian Journal' for 1857, p. 224), that "he himself had been for twenty years under a sort of druidical training with his father, and that the system was of so sublime and intellectual a nature, that unless he could find some one qualified in such a way as to be a worthy member of the order the secret should die with him." The hope, therefore, of developing the mystery, such as it is, might be abandoned, but for the declaration of the Rev. John Williams ab Ithel, in the 'Cambrian Journal,' of which he is the editor (1857, p. 57): "Much of the real Cyvrinach alluded to is still extant, as we ourselves can testify, and we sincerely trust that measures will be adopted by the Welsh Manuscript Society for the speedy publication of the whole. Until this is done, the early literature and history of our country can never be properly understood."

Much doubt was also thrown on the discovery of the 'Coelbren y Beirdd," or Alphabet of the Bards, an alphabet resembling the Runic, which was also brought forward by Iolo Morganwg, and an essay on its genuineness was proposed as the subject of a prize at an Eisteddvod in 1840. When the author of the successful essay was sought for by opening the envelope containing his name, it was found to be Taliesin Williams, or, as he was proud to call himself, Ab Iolo, who thus strove to vindicate the fair fame of his father. The dissertation is pronounced by impartial critics, Dr. Williams of Llangadwaladr, and Dr. Tregelles, to be a masterpiece, and the author is said to have shown satisfactorily that there were traces of the alphabet in Welsh literature long before his father's time. Since then, it has apparently been assumed by some Welsh writers, not only that the history of this alphabet, tracing it back to the Creation, was shown to be Elizabethan, or mediæval, but was also shown to be druidical, and—strangest of all—authentic. There are many illiterate persons who suppose that a statement must necessarily be true because it has appeared in print, but some of the Welsh critics carry the point still farther, and apparently believe everything they find in manuscript.

The three associates of the 'Myvyrian Archaiology' had each but one son, and in each case the son became an eminent man. Taliesin Williams, or Ab Iolo, the son of Edward Williams, or Iolo Morganwg, who has been already so frequently mentioned, was for the greater part of his life a schoolmaster at Merthyr-Tydvil. He was born in 1787, and died in 1847. Like his father, he wrote both Welsh and English poetry. Aneurin Owen, the son of William Owen Pughe, never took the name of Pughe, assumed by his father. His edition of the 'Laws of Wales,' already mentioned, is a lasting title to remembrance. He was born in 1792, and died in 1851. The son of Owen Jones, still living, is Owen Jones the eminent architect, who produced, in conjunction with Goury and Gayangos, the finest work on the Alhambra of Granada; and afterwards reproduced, with signal magnificence, the Alhambra itself at Sydenham, where he employed, in the decoration of a second Crystal Palace, the talents which had largely contributed to the success of the first.

One of the most eminent writers on Welsh antiquities of the commencement of the century, was the Rev. Edward Davies, born in Radnorshire in 1756, who died, after a long illness, on the first day of the year 1831. He first essayed his powers in works of imagination—'Aphtharte,' a poem, and 'Eliza Powell, or the Trials of Sensibility,' a novel; but his chief productions were 'Celtic Researches,' published in 1804, and the 'Mythology of the Druids,' published in 1809, two volumes of no inconsiderable ingenuity and learning, employed in the support of a singular theory. According to Davies the druidical superstition was preserved and patronised in Wales, in an esoteric fashion, down to the time of Edward I., and was a form of worship in which the bull, the horse, and the element of fire were prominent emblems. "If this be genuine British heathenism," he remarks, "it will be expected that vestiges of it should be discovered in the oldest bards now extant, and here, in fact, they present themselves in horrid profusion." The translations of Davies are made in so peculiar a fashion, that he turns the Gododin of Aneurin into a description, not of a battle at Cattraeth, but of the massacre at Stonehenge; and indeed in his hands, it is difficult to see what any passage may not prove. He is, as might be expected, severe in his criticism on Iolo Morganwg and his 'Bardic Triads,' of the genuineness of which he distinctly intimated his disbelief in 1809; but his own views are in many cases evidently fanciful, though they have been supported, even in later years, by writers of learning. Davies, towards the close of his life, received one of the literary pensions of 100 guineas, paid by George IV. to the nominees of the Royal Society of Literature.

The Rev. Thomas Price, another eminent Welsh antiquary, was a much safer and more candid guide than most of those who have been equally enthusiastic in the cause of his country's language and literature. He observed, in his 'Hanes Cymru,' while praising the care which had been taken to collect and print all the alleged productions of the primitive bards in the Myvyrian Archaiology, that it was only necessary to turn over the pages to see that some of the pieces did not, and could not, belong to the names they were ascribed to, and he acknowledged the difficulties with regard to the 'Historic Triads' and other documents, which are often quoted by others without a hint of unsoundness. Thomas Price was, like Edward Williams, the son of a stonemason, but of a stonemason who, having formed an attachment to a clergyman's daughter, had qualified himself to become a clergyman, and died a Welsh pluralist with a salary of fifty pounds a year. Mr. Price himself, who was born in 1787, and died in 1848, at the age of sixty-one, rose no higher in the church than to the vicarage of Cwmdu. He was so indefatigable a writer in Welsh periodicals, chiefly under the signature of "Carnhuanawc," that he contributed to fifteen, and wrote an article for one or the other of them every month. His chief production in Welsh is the 'Hanes Cymru a chenedl y Cymry' (published in numbers between 1836 and 1842), a 'History of Wales and the Welsh nation from the earliest times to the death of Llewellyn,' after which it is indeed continued, but on a very meagre scale. It is the only history of Wales in Welsh at all commensurate in size and importance with the histories of Wales in English by Warrington and Woodward. It comprises not only a political, but a literary history of the country during most of the period that it embraces, and well merits a translation. The best of his English works are collected in the 'Literary Remains of the Rev. Thomas Price, with a Memoir of his Life by Jane Williams,' in two volumes (1854-55), the correspondence in which presents, it has been remarked, the fullest picture yet drawn of a Welsh literary life.

One of the few instances of Welsh scholars who have obtained distinction in some other walk is afforded by the Rev. John Williams, archdeacon of Cardigan, author of 'Homer' and 'Gomer,' the former a treatise on the Greek poet, and the latter on the Welsh language. Born in 1792, and sent from the school at Ludlow to Balliol College, Oxford, Williams was fortunate enough to meet with Lockhart as a fellow-student, and to form a friendship with him which influenced his whole future career. Recommended by Lockhart as tutor to the second son of Sir Walter Scott, he obtained, by Sir Walter's support, in 1824, the rectorship of the new Edinburgh Academy, a sort of rival to the old High School and formed one of the circle of the great poet and romancer, over whose remains he finally read the funeral service in Dryburgh Abbey. His success as a teacher was marked, and the first 'Dux' in his school was Archibald Tait, the present bishop of London. After twenty years of life in Scotland, he returned to Wales, to the vicarage of Lampeter and the archdeaconry of Cardigan, and continued a career of authorship till his death at Bushey Heath in December, 1858. His best known work was a life of Alexander the Great, and as archdeacon of Cardigan, his ecclesiastical superior was the Bishop of St. David's, Dr. Connop Thirlwall, author of the celebrated 'History of Greece.' Both bishop and archdeacon were also Welsh scholars; but Thirlwall acquired the language after his accession to the bishopric; Williams had always been noted for his attachment to his country's language and literature, and was zealous in Scotland for the honour of Wales. His writings on Welsh subjects, however, did not raise his reputation. In 'Gomer,' a dissertation on the early forms and history of the language, he expressed himself with such positiveness on doubtful subjects, and such vehemence on unimportant ones, as to weaken his authority. He had announced a translation of the poems of Aneurin, Taliesin, and the other primitive bards, with a critical revision and re-establishment of the text, which was looked for with much interest; but though the announcement was made in 1841, nothing had been done towards carrying it out at his death in 1858.

Among the most eminent of living Welsh antiquaries is another John Williams, the Rev. John Williams ab Ithel, rector of Llanymowddwy, Merionethshire, and editor of the 'Cambrian Journal,' gainer of the prizes at numerous Eisteddvods, and author of numerous works on Cambrian subjects. Ab Ithel is an ardent believer in the discoveries and disclosures of the last seventy years, with regard to Cambrian history. In the year 1856 he edited, for the Welsh Manuscript Society, the 'Grammar of Edeyrn the Golden Tongued,' said to be composed about the year 1270, and to which Mr. Williams added a translation and copious notes. The first note is as follows:—"The British alphabet is said to be of divine origin. God in the beginning announced His name, and said /|\, whereupon all things sprang simultaneously into life and being, and responded in a shout of extatic joy, /|\. At the same time there appeared three rays of light, forming the divine name and the three first letters, which were also the source of all letters and sciences. Einigan Gawr, who was favoured with this sight, took three rods of mountain ash, and inscribed upon them the name of the Deity, but the people that saw them mistook the rods, thus bearing His name, for God himself, which caused Einigan to die of grief. (See Coelbren y Beirdd, pp. 6, 7, Iolo Manuscripts, p. 424.) After his decease, Menw ap y Teirgwaedd received a knowledge of the primary alphabet, and developed it, as it would seem, to the extent of ten letters. These letters, or, as they were originally termed, awgrymmau (signs), coelbrai (omen-marks), or ystorrynau (cuttings), were kept a secret by the Bards until the time of Beli Mawr, or, as Llywelyn Sion says, even unto his own day. (Iolo Manuscripts, pp. 617, 618, 623.)" As Llewelyn Sion, of Llangewyd, of whom we have so often had occasion to speak, died about the year 1616, it must be acknowledged that this was the best kept secret on record. Mr. Williams, it will be observed, speaks of these statements, in regard to the British alphabet, not as the dreams of insanity, but as disclosures to be received with respect. He adopts the same serious tone in the preface to the 'Brut y Tywysogion, or the Chronicle of the Princes,' edited by him in 1860, and 'published by the authority of the Lords Commissioners of Her Majesty's Treasury, under the direction of the Master of the Rolls.' "The voice of tradition," he begins, "would not lead us to suppose that the ancient Britons paid any very particular attention to the study of chronology previous to the era of Prydain, son of Aedd the Great, which is variously dated from the year 1780 to 480 before the nativity of Christ." The remarks which follow are of a similar character. Ab Ithel is now (1861) publishing 'The Traditionary Annals of the Cymry; reprinted from the Cambrian Journal,' in which many of the statements are based on the manuscript of Llewelyn Sion, and many others on what are simply quoted as "unpublished manuscripts."

A more complete contrast to Ab Ithel, in the character of his criticism, can hardly be imagined than Mr. Thomas Stephens, of Merthyr-Tydvil, acknowledged even by his opponents to be one of the first of living Welsh scholars. In his 'Studies on British Biography,' printed in the 'Cambrian Journal' in which the editor is in the habit of speaking of Prydain ab Aedd Mawr as a personage as historical as Llewelyn ab Jorwerth, or William the Conqueror, Mr. Stephens remarks that "it is seldom that a name can be clearly demonstrated to be a myth, and the stages of its growth fully and satisfactorily unfolded, but we are enabled to do this in the case of Prydain ab Aedd Mawr, and to show that the name is one of the best specimens of a myth in all literature." "On me be the shame," he adds, "if the statement is not borne out by the facts and reasons here following: on those who have deluded their countrymen with dreamy speculations and hardy mis-statements, if the proof should be conclusive." Mr. Stephens forcibly describes himself at the end of his article, as one "who honestly endeavours to unfold the real history of his country and countrymen, and who aspires to teach them that that can be no true patriotism which upholds as veritable history a tissue of demonstrable fictions, which fears to realise its own boast of 'Truth against the world,' and dreads nothing so much as to see its 'traditions' subjected to a rigorous examination 'in the face of the sun and in the eye of light.'" The most important work hitherto published by Mr. Stephens is his valuable volume on the 'Literature of the Cymry in the Twelfth and following Centuries.' The reader, even where he cannot agree with the author's opinions, feels assured that they are those, not only of a man of learning, but of sincerity and judgment. A complete history of Welsh literature from the same pen would be a boon, not only to the literature of England, but of Europe, and the gratitude of men of letters would make amends to Mr. Stephens for the virulence with which he has been sometimes assailed by the mistaken patriotism of ill-judging countrymen, who do not perceive that he is one of the best friends and supporters of the real honour of Wales.

It has been already mentioned that Mr. Stephens's general views have found a powerful supporter, and in some cases extender, in Mr. Nash of Cheltenham. They are also substantially those adopted in the able 'History of Wales' from the earliest times to the incorporation with England, by Mr. Bernard Woodward, librarian to the Queen. Much excellent criticism on Welsh Druidism, Bardism, and literature may be found embodied to the greatest advantage in a volume which is distinguished for the vivacity, as well as the general soundness of its views.

The music of Wales was first brought before the English public, in connection with its poetry, in the 'Relics of the Welsh Bards,' published in 1784, by Edward Jones, "Bard to the Prince of Wales," a native of Merionethshire, who died at London in 1824. The work is valuable from the specimens it contains of both poetry and music, but the poetry is too paraphrastically rendered, and the accompanying notices are little to be relied on. A similar collection of Welsh tunes was made by John Parry (born at Denbigh in 1776, died at London in 1851), a self-taught musician, who became composer to Vauxhall Gardens, and was moreover honoured with the degree of "Bardd Alaw," or Bard of Music, at a congress of Bards, in 1821. Mr. Parry had the good fortune to engage Mrs. Hemans to write the verses to his collection of melodies; but Mrs. Hemans, though she spent part of her childhood and much of her life in Wales, and was attached to the country, was unacquainted with the language. Another collection of Welsh tunes is now announced as in preparation, with Welsh words, by "Talhaiarn," one of the first of living Welsh poets, and translations into English verse by Mr. Thomas Oliphant, of the Madrigal Society, author of the 'Musa Madrigalesca.'

The quantity of Welsh poetry, or verse, that has been written during the last hundred years is very remarkable, and not the less remarkable is the general uniformity of its character. It is almost exclusively lyrical. In the whole range of Welsh literature for many centuries there was nothing of the epic or narrative kind, not even so much as a ballad, while the most popular volume of Breton poetry that has been published, the 'Barzas Breiz,' consists of a collection of ballads gathered among the peasantry. An absence of fiction in prose, of that class which the Germans consider a branch of poetry, is also very striking in Welsh literature. It might be brought as an argument against the originality of the Mabinogion, that the only other fictitious narratives that have been popular in Wales, even down to our own times, have certainly been imported. The 'Pilgrim's Progress' is simply a translation of Bunyan; the 'Sleeping Bard' of Ellis Wynne is founded on Quevedo; and the only book of the kind that has [illegible] the mind of the Welsh in our days is 'Uncle Tom's Cabin,' which received the extraordinary honour of four different translations and adaptations. All these works, it may be remarked, partake of a religious character. We have never heard of a Welsh translation of 'Robinson Crusoe,' or of a novel by Sir Walter Scott. Some 'Temperance Tales' have lately been produced in answer to prizes, and we observe that with the present year (1861) a serial was commenced at Llanerchymedd under the title of 'Y Nofelydd,' 'The Novelist.' If well conducted, we heartily wish it success. The "Cymro uniaith"—the Welshman who knows no language but Welsh, has been left singularly deficient in means of literary recreation. The Saxon could hardly be more ignorant of the literature of Wales than such a "Cymro uniaith" necessarily was, till very recently, of the literature of England.

Some of the poets of the more recent period have already been mentioned in giving an account of the antiquaries,—Owen Pughe, Edward Williams, and his son Taliesin; of the others, the only dramatic one may take precedence. "Twm o'r Nant," says Williams, or Iolo Morganwg, in one of his letters, "has been called the Shakspere of Wales. What blasphemy to name him with the Shakspere of England! You have most probably seen a foolish crambo sometimes put into the hands of little children beginning to read, 'This is the House that Jack built.' It is much fairer to compare this to the writings of Shakspere than anything that was ever written by Twm o'r Nant, whose interludes consist of nothing but the lowest and frequently the most indecent buffoonery that can be imagined." "Twm o'r Nant," or "Tom of the Valley," was the bardic name of Thomas Edwards, who was the originator and chief of a band of strolling players who went about to the Welsh villages. His interludes, "Enterlutes," as he calls them in Welsh, resemble, if we may judge by their titles, which are given by a correspondent in the 'Gwladgarwr' (vol. vi., p. 144), the Mysteries or Moralities, which preceded the establishment of the regular theatre in most countries of Europe. One of them is a dialogue between a Protestant and a Dissenter; another between Pleasure and Misery. The dates of these are 1783 and 1787. He afterwards advanced nearer to the regular drama, for in 1812 we have the 'Ystori Richard Whittington yr hwn a fu dair gwaith yn Arglwydd Maer Llundain;' the story of Whittington thrice lord mayor of London. Their merit, we may charitably suppose, was greater than Williams allows them, since some who deny him the name of the Welsh Shakspere call him the Welsh Aristophanes. Edwards was born in Denbighshire in 173[illegible], and died, apparently, before 1820. Before his time the only existing specimens of the Welsh drama, that we are aware of, are a volume of "interludes" of the 17th century, among the manuscripts of the British Museum. Since his time we have heard of no attempt to revive the acted drama in Wales; but in a recent number of 'Y Beirniad,' a periodical, there is an adaptation of David and Goliath from the original of Hannah More; and Talhaiarn gives in his poems a translation of a scene or two from Shakspere's 'King Lear.'

The poetry of the fourth period in Wales is generally of a serious character. Three Davids are mentioned as distinguished among the bards—David Richards of Dolgelly (1751–1827), known as Davydd Ionawr; David Thomas of Caernarvon (1769–1822), known as Davydd Ddu Eryri; and David Owen of Eivion (1784–1841), by his bardic name Dewi Wyn. Davydd Ionawr is sometimes called "the Christian poet of Wales," his chief productions being a sort of epic on the Trinity, and a paraphrase of the history of Joseph. Davydd Ddu Eryri was one of the companions of Iolo Morganwg in the bardic meeting held in 1792 on the summit of Primrose Hill, and in 1793 and 1794 he was, with his rival, Walter Davies, or Gwallter Mechain, prohibited from contending at Eisteddvods for a time, because, when they did so, their competitors had no chance of success. Dewi Wyn spent his life in rural pursuits, and his poems were collected in a volume under the title of 'Blodau Arfon,' or 'Flowers of Arvon.' Mr. Thomas Lloyd Jones (Gwenffrwd), of Holywell, in Flintshire, who emigrated to America, and died in Alabama in 1834, in his twenty-fourth year, published a small but useful volume, 'Ceinion Awen y Cymry,' 'the Beauties of Welsh Poetry,' an acceptable guide both to the stranger and native. A larger volume of this description, with biographical notices of the poets, on the plan of Mackenzie's 'Specimens of Gaelic Poetry,' is much required in Welsh literature. Lloyd Jones had also translated into Welsh, Thomson's 'Seasons,' and the 'Deserted Village,' and thus set an example, which has been followed by Daniel Silvan Evans and by —— Jones (Talhaiarn), of enabling the Welsh reader to taste some of the beauties of the bards of England. Merthyr-Tydvil at one time boasted of three poets—Taliesin Williams, already repeatedly mentioned; Edward Williams, an innkeeper, who, to distinguish him from the more famous Edward Williams, or Iolo Morganwg, was called Iolo Mynwy; and John Thomas, said by his admirers to be the best minstrel in South Wales. Two eminent Welsh bards were resident at Oxford together—the Rev. Daniel Evans, of Jesus College, who assumed the name of Daniel Ddu o Geredigion, from his native Cardigan, and the Rev. John Jones, of Christ Church, who took that of Tegid, from having been born near Llyn Tegid. A collection of poems by the former was published at Llandovery in 1831, under the name of 'Gwinllan y Bardd,' 'The Poet's Vineyard.' The productions of the other have not yet, that we are aware, been collected, though the death of Tegid took place some years ago, and his poems are such as his countrymen would not willingly let die. The Rev. Walter Davies, called Gwallter Mechain, from his birthplace, Llanvechain, in Montgomeryshire, was born in 1761, and died in 1849, in his eighty-ninth year, still an active contributor to Welsh periodicals, for which he had then been in the habit of writing for more than half a century. As a Welsh poet he was more remarkable than his friend Iolo Morganwg, and his influence at the Eisteddvod of 1819 was strong against Cynghanedd. The Rev. James Hughes, born in 1779, at first a peasant in Cardiganshire, then a workman in Deptford dockyard from his twenty-first to his forty-fifth year, became, in 1810, a Calvinistic Methodist preacher, was for many years minister in Jewin Crescent Chapel, and died in 1846. His Welsh commentary on the New Testament is in high esteem, and he was also considered a good poet and critic. Among his productions is a translation of Gray's 'Bard.' Some Welsh verses are inscribed on his tombstone in Bunhill Fields burying-ground, in full view of the passengers along the busy City Road, whose eye they often catch. The Rev. William Rees, of Liverpool (Gwilym Hiraethog), is a poet of high reputation, who generally exercises his pen on serious subjects, and the chief production in whose volume of poems is a paraphrase on the Book of Job. The Rev. William Williams, of Caernarvon (Gwilym Caledfryn), author of 'Grawn Awen' ('The Treasure of the Muse'), and other volumes of poetry, has been for the last forty years one of the leaders of the poetical choir. It is somewhat remarkable that we hear of no "tenth Muse," no poetess whatever in the Welsh Parnassus, though of late even female preachers and female lecturers have been numerous in the country, and its history and literature owe permanent obligations to the Englishwoman Mrs. Hemans and the Scotchwoman Lady Charlotte Guest. A poem entitled 'Wales,' which has appeared in America, is a tribute to her native country by Miss Maria James, who, when she left the Old World at the age of eight, was acquainted with no language but Welsh, and whose first lesson in English was to learn on board the vessel the meaning of "Get out of the way." But even in her tribute to Wales she adopted the English language. One good effect of the prizes proposed by the Welsh societies has been that of late some versified narrative has been introduced to give a little more variety to Welsh poetry. It is singular to observe with what undeviating constancy the national mind has run for centuries in the track of funeral elegies and eulogies, so that, even in modern times, scarcely any respectable clergyman is lost to his congregation without being celebrated in verse. The poet whose Bardic name is Talhaiarn, but whose real name is —— Jones, seems to offer an exception in many respects to the general course of his countrymen. He writes poetry in English as well as Welsh; he appears to appreciate and enjoy English literature; and his productions are of a lighter and more amusing kind than usual. A long residence abroad, not only in England, but in France, in pursuit of his profession as an architect, appears to have emancipated him from many of the narrow ideas which are still found in the glens of Wales.

The cultivation of Welsh prose has lately taken a much wider range than formerly, owing to the great spread of periodical publications. Of separate works there are few, except of a purely theological cast, and these are generally commentaries on the Scriptures, in which the matter is taken from English commentators, and only arranged in a new manner. The Rev. Thomas Price's 'Hanes Cymru,' a history of Wales which has been already noticed, is almost the only volume of original research. A volume entitled 'Brutusiana sef Casgliad Detholedig o'i Cyfansoddiadau' ('Brutusiana, or a Select Collection of his Compositions'), by David Owen, who writes under the signature of Brutus, is considered to contain some of the best specimens of modern Welsh prose, which are chiefly reprinted from the periodical entitled 'Yr Haul,' of which Mr. Owen was editor. The subjects are mostly religious. Mr. Hugh Williams, known under the bardic name of Cadvan, and formerly editor of the 'Cymro,' a newspaper published at Bangor, is also celebrated as a writer of elegant and idiomatic Welsh prose, and was presented with a testimonial on that account by his countrymen in London, in May, 1860. Mr. Williams is one of the translators into Welsh of 'Uncle Tom's Cabin.'

The spread of Methodism in Wales has been referred to as one of the causes of the revival and extension of its literature, and the proof is at hand in the fact, that no other literature whatever is so eminently sectarian. Methodism in Wales, as elsewhere, has found its chief acceptance among the lower classes. In England the Methodists have a literature of their own, but it is couched in the common language of the country; in Wales that literature is in the peculiar language of the peasantry. The peasantry are delighted beyond measure to hear themselves addressed from the pulpit in their native tongue. The two popular preachers of Anglesey, Christmas Evans (1766–1838) and John Elias (1774–1841), produced wonderful effects on their Welsh congregations. Christmas Evans, so baptised because he was born on Christmas-day, was noted for his fine voice and his theatrical action. John Elias, who paid a visit to London every three years, and also took tours through England, preaching in Welsh in towns where no other Welsh sermon had ever been heard, was a sort of apostle to his countrymen. The great body of modern Welsh literature is thus of a theological and sectarian cast, and it is supported by many to whom nationality and national traditions are a matter of comparative indifference. There are also many, to whom theological disputes are matters of less interest, but who are enthusiastic for their nationality and their language. Between the two are all shades of combinations of the two feelings—theological and national; and the progress of both is more faithfully delineated than anywhere else in the Welsh periodical press. In almost every country the periodical portion of its literature has now assumed an importance unknown to previous stages of its history, but in no country is it so predominant as in Wales.

The first Welsh periodical of any kind appeared about 1770: its title was 'Yr Eurgrawn Cymraeg,' or the 'Welsh Treasure,' and it was edited by the Rev. Peter Williams, of Caermarthen, and Evan Thomas, a Welsh poet, from Montgomeryshire, then resident in that town. Allusion has already been made to 'Y Greal,' or 'The Miscellany,' which was set on foot by Owen Jones, under the editorship of Owen Pughe, in 1805, and did not proceed further than one volume. The 'Seren Gomer,' or 'Star of Gomer,' was the first periodical that achieved a decided success in Wales. There are three different stages of its career,—as a weekly newspaper, a monthly magazine, and a quarterly miscellany. The first number of it appeared at Swansea, on Saturday, the 1st of January, 1814, and was the first Welsh newspaper ever printed. Its object was stated by the editor, in his opening address, to be to arrest or prevent the extinction of the language, which it appears was then expected by many not to survive that generation. The editor, the Rev. Joseph Harris, a Baptist minister of Swansea, was a self-taught man, who carried his admiration of his native language to a fanatical extent. The 'Seren Gomer' newspaper was at first very successful, but its supporters soon began to cool and fall off, and it came to a close with No. 85, in 1815, the proprietors, six in number, suffering it is said a loss of 1000*l.* by the enterprise. In 1818, it was resumed as a monthly magazine at Caermarthen, under the same title and with the same editor; but this time it had more of a sectarian character, and it struck deep root. Even the loss of its editor, Harris, did not check its success: he died in 1825, of a broken heart at the loss of his only son, who had died the year before at the age of twenty-one, and was already known, under the name of Jeuan Glan Tawy, as a poet of merit. The 'Seren Gomer' continued to be for many years the most popular magazine in Wales, though its success gave birth to several rivals. Its general character was that of the English magazines of the early part of the 19th century, the contents consisting mainly of articles from chance contributors, and every number comprising a digest of foreign and domestic news, with the state of the markets, so as to give the reader the advantage of a monthly newspaper. Questions of theology and church government took however such a prominence in its columns, as would have caused it to be classed in England among the religious magazines, such as the 'Evangelical,' or the 'Baptist.' Its price as a monthly magazine was sixpence; it is now raised to a shilling, and the 'Seren Gomer' of 1861 is a quarterly publication.

Several of the other periodicals which arose in consequence of its success were connected with religious bodies. 'Y Drysorfa,' or 'The Treasury,' edited by John Parry, and commenced in 1831, was under the superintendence of the Calvinists. 'Y Diwygiwr,' or 'The Reformer,' commenced at Llanelly in 1836, was conducted by a committee of the Independents; and 'Y Dysgedydd,' or 'The Teacher, published for the last thirty years at Dolgelly, is edited by six or seven Congregational ministers. Most of the other magazines are organs of Wesleyans, Independents, Baptists, or Universalists. The 'Cylchgrawn,' or 'Circulator,' consisting principally of translations from the publications of the Society for the Diffusion of Useful Knowledge, in particular the 'Penny Magazine,' and 'Penny Cyclopædia,' had a very short career, in consequence of the distaste of the Welsh public for all but religious publications. It was commenced in 1834, and discontinued in 1835. Its editor was the Rev. John Blackwell, of Mold, in Flintshire, who had raised himself from the position of a shoemaker to that of rector of Meinordeifi, in Cardiganshire, and had some poetical reputation. Other publications were more successful, which, though not excluding sectarian matter, had a strong tincture of literature. 'Y Gwladgarwr,' or 'The Patriot,' published at Chester and Liverpool from 1833 to 1841, under the editorship originally of the Rev. Evan Evans (Jeuan Glan Geirionydd), contains amusing and instructive biographical articles. 'Yr Haul,' or 'The Sun,' published by Rees of Llandovery, though espousing the interests of the Established Church, was edited by a layman, David Owen, and contained some valuable and non-ecclesiastical matter. But the leading literary organ of Wales for some years has been a quarterly periodical entitled 'Y Traethodydd,' or 'The Essayist,' commenced in 1845 at Denbigh. This is a production of a class answering to the English quarterly reviews, the articles in it being all of a superior character, and supplied by paid contributors. It takes a wider and freer range than its predecessors, and is the only Welsh periodical which contains, for instance, an "essay" on Goethe's 'Faust,' and another on Kant's 'Philosophy.' Many of its articles well merit translation: we may cite, as an instance, a curious account of the French invasion at Fishguard, much fuller, we believe, than any that has yet appeared in English. Since 1859 a companion has arisen to the 'Traethodydd' in 'Talicsin,' a quarterly magazine issued at Ruthyn, which publishes the productions, both poetical and in prose, which have received the prizes at the Eisteddvods, in addition to reviews of new books and miscellaneous articles. The Welsh periodicals form altogether the most striking and attractive feature in their modern literature. Their number is astonishing, and they are issued even in secluded towns and villages. In the catalogue of the periodical publications in the Library of the British Museum, we find two Welsh magazines published at Llangollen, three at Llanidloes, and four at Llanelly. An interesting notice of them was given in some articles of the 'Athenæum' (8th and 15th November, 1856), which enumerated sixteen magazines and six newspapers. The leading newspaper is the 'Amserau' (the 'Times'), published at Liverpool, whose circulation was computed in the 'Athenæum,' but no doubt very erroneously, at 100,000. Penny newspapers are now numerous and well conducted. 'Yr Herald Cymraeg,' published at Caernarvon, and 'Yr Udgorn y Bobl' ('The People's Trumpet'), published at Denbigh, contain letters from correspondents at London, Liverpool, Dublin, Hirwaun, &c., &c., which though not remarkable for purity of language, furnish much more amusing reading than was formerly within reach of the Welsh reader. It was mentioned in the 'Athenæum' that a selection of extracts from the Welsh periodicals was issued at New York, under the title of 'Y Detholydd,' or 'The Selector,' and that there were also original Welsh periodicals in America: 'Y Cenhadwr' ('The Messenger'), 'Y Seren' ('The Star'), 'Y Cyfaill o'r Hen Wlad' ('The Friend from the Old Country'), "and many others." Samuel Jenkins, of Philadelphia, who contributes a letter on eminent Welshmen to a book by Alexander Jones on the Welsh in America, entitled 'The Cymry of '76,' published at New York in 1855, mentions that of four Welsh magazines then published in the United States, one was issued in the city of New York, two in towns in Oneida county, and the other in Pottsville, Pennsylvania. We have also seen mentioned a newspaper at New York, 'Y Cymro Americanaidd' ('The American Welshman'), which is said to have 5000 subscribers. In an enumeration of the newspapers published in America in 1861, it is stated that there are five in the Welsh language,—and, we believe, exactly four thousand in the English.

One of the greatest enterprises of Welsh publishing is the Welsh Encyclopædia, commenced by Mr. Gee, of Denbigh, in the year 1856, under the editorship of the Rev. John Parry, of Bala. Its title is 'Encyclopædia Cambrensis-Y Gwyddoniadur Cymreig.' It is divided, on the plan of the 'English Cyclopædia,' into several sections, of which the first, which is now publishing, is that of Divinity, Philosophy, and Antiquities. The first number of the fourth volume, just issued (in August, 1861), carries it to the article *Dyfnwal Moelmud,* in which, as in the article on *Bardd,* which occupies 36 closely-printed pages, a full and impartial account is given of the views of both of the parties in Welsh antiquities, but in a manner which leaves no doubt that the writer's judgment is adverse to the supporters of Bardic tradition. The Encyclopædia is a work which in its literary character does honour to Welsh literature, and in its typographical execution does honour to the Welsh press.

This is perhaps the most appropriate place to mention that some of the most valuable information in print with regard to the literature of Wales is comprised in five periodicals in the English language, devoted exclusively to Welsh subjects. The earliest of these, 'The Cambrian Register,' extends to three volumes, the first of which was published in 1796, the second in 1799, and the third in 1818. It would be difficult to name three volumes of a periodical publication more rich in original information of interest. The letters of distinguished Welsh antiquaries, which form a portion of its contents, are particularly entertaining; and a history of Welsh poetry, which appears in the first volume, contains more information on the subject of its recent authors than will be found elsewhere. Dr. Owen Pughe was one of its principal contributors, and is said to have been its editor. 'The Cambro-Briton and General Celtic Repository,' also in three volumes, published in the years 1819—1822, is an excellent periodical, replete with information of every kind, and remarkably free from frivolous or unimportant matter. Its editor was Mr. John Humffreys Parry, secretary to the Cymmrodorion Society, author of the 'Cambrian Plutarch' and other works of reputation. The 'Cambrian Quarterly Magazine,' in five volumes, published from 1829 to 1833, is unfavourably distinguished from its predecessors by the admission of articles of mere light reading: but some of these are extremely well written. The present successor to these works is the 'Cambrian Journal, published under the auspices of the Cambrian Institute,' and edited by the Rev. John Williams ab Ithel. It was commenced in 1854, and the four quarterly numbers form a volume each year. The articles are of a very varied kind, and of extremely different degrees of merit, and opinions of the most opposite character are freely and strongly expressed. The 'Archæologia Cambrensis,' or 'Journal of the Cambrian Archæological Association,' though of course less devoted to literary subjects than the other periodicals, contains a good deal that bears upon them. It has produced an annual volume of four quarterly numbers, with occasional supplements, since its commencement in 1846. The editor is the secretary of the society, the Rev. Longueville Jones. The volumes of these periodicals, now about thirty in number, should find a place in every public library in England, where the literature of ancient Britain and the literature of a considerable portion of it, are not objects of ence. They comprise almost all the information on the present accessible to the English reader—defective in many it is true, and scattered over many volumes; but we can scarcely plain of the deficiency of a general and satisfactory survey literature of Wales, while as yet we have nothing of a similar our own.

In speaking of the periodicals we have anticipated some of our mation with regard to societies. The literary associations of though not very successful at first, have been in the long run effectual in reviving the taste for its literature. The earliest of seems to have been the Cymmrodorion (Associates) or Metropolitan brian Institution, which was originally established in London in immediate purpose was to cultivate the language and literature of and its members were also to "contribute their endeavours towards instruction of the ignorant and the relief of the distressed part of countrymen." It collected some scarce books and manuscripts re to Wales, which were afterwards deposited in the library of Welsh school in Gray's Inn Lane, but did little else in a literary of view, and after an existence of thirty years appears to gradually expired of inaction. Its place was more vigorously oc by the Gwyneddigion, or Society of the Men of Gwynedd, or Wales, which was established in London in 1771, by that indefatig patriot Owen Jones of Myvyr. This association at different patronised various literary works connected with the principality its chief aim was to keep alive the attachment to the national and poetry. With this view it revived the ancient congresses of bards, and distributed medals among the best performers on national instrument, the harp, and the writers of the best poems on subjects selected annually for the occasion. In 17 "Eisteddvod" was held under the auspices of Owen Jones, at Caerw in Flintshire, which prepared the way for the "Eisteddvods" of recent times. The London Cymreigyddion Society, founded in was intended to place the natives of Wales on something of equality with the natives of Great Britain, in respect of the opp tunities of acquiring useful knowledge; and for this purpose meetings once a month were to be devoted to the delivery of lectur in the Welsh language on scientific and useful subjects, many of wh were printed and published. This society now appears to be ext and one of its last public acts was to reward in 1840, the Rev. Bray for his 'Essay on the Means of Promoting the Literature Wales,' in which he recommended the systematic discouragement the Welsh language. The second "Cymmrodorion" Society wa formed in 1820, at a meeting held at the Freemasons' Tavern, has similar objects with the first. It commenced the publicati of its 'Transactions' in 1822, and completed a second volume 1843, after which it appears to have come to a stand-still. Th "Society for the Publication of Ancient Welsh Manuscripts," founded at Abergavenny in 1837, and was announced in its prospectus to be acting in conjunction with the "Cymmrodorion Society, founded at London in 1750," by which the second Cymmrodorion Society wa probably meant, though the date given is anterior even to the formation of the first. The Manuscript Society after issuing the 'Liber Landavensis,' or the 'Ancient Register of the Cathedral Church Llandaff,' in Latin and English, under the editorship of the Rev. W J. Rees, the 'Heraldic Visitation of Wales,' the 'Lives of the Welsh Saints,' and other valuable publications, the Iolo Manuscripts, and the 'Grammar of Edeyrn,' appears to have fallen into a state of languor. It was recently announced, however, as already stated, that measures are about to be taken for restoring its vigour.

The Cambrian Institute, founded in 1853, has held a few occasional meetings in London, and has a number of sectional committees and local secretaries, but its activity is chiefly displayed in the publication of the 'Cambrian Journal,' which is circulated among its subscribers. It is remarkable that one of its earliest patrons and its present president is Prince Louis Lucien Bonaparte, nephew of Napoleon I., and cousin of the present Emperor of the French, who has in many ways distinguished himself as a cultivator and student of the Celtic languages as well as of others of the less known tongues of Europe. The Prince was born in England, and on the Welsh border, at the time that his father, Lucien Bonaparte, was resident in this country, during the reign of the first Napoleon. Another distinguished name in the list of the Institute is that of the poet-laureate, Alfred Tennyson—a peculiarly appropriate one, not only because Tennyson has given fresh brilliancy in our time to the legends of King Arthur, but because the office he holds is one peculiarly in keeping with Cambrian notions of privileged bards and poets named by authority. The first poet-laureate of the English court was appointed in the reign of Edward IV., who is said in some Welsh Guide-Books to have been born in Wales.

While the Societies have, as a general rule, been somewhat inert, a brilliant success has attended the revival of the Eisteddvodau (literally 'sessions'), or meetings for poetry and music, such as were first re-inaugurated in 1798 by Owen Jones, who seems to have had a happy tact in discovering what was likely to succeed, though he was himself in advance of his time. Their progress was obscure till 1819, when one was held at Caermarthen, under the presidency of Dr. Burgess, then bishop of St. David's, but in reality prompted and supported by Dr. Joseph Harris, the Baptist editor of the 'Seren Gomer,' and conducted and enlivened by Iolo Morganwg, who completely took the lead and put in practice many of the ideas which appear in the notes to his 'Ode on Primrose Hill.' This Eisteddvod was so successful as to form an epoch in their history, and ever since they have been becoming more frequent and more popular. The idea at the basis of such meetings, that of holding a sort of Fair for poetry and music, is one that was practised in the "singer's festivals" of the Minne-singers and the floral games of the Troubadours, and even among the Arabs before Mohammed, whose poetical rivalries at the fair of Ocadh gave rise to the 'Moallakat,' which are some of the most classical compositions of Arabic literature. The same principle received a new application in the Fairs for Science introduced by Oken in Germany in 1822, on the model of a meeting of naturalists in Switzerland in 1815, and the idea was imported from Germany to England by the foundation of the British Association in 1831. Meetings of agriculturists, archæologists, orientalists, men of science, and others, are now held in many parts of Europe, but fairs for poetry and authorship appear to be still peculiar in modern times to Wales and Provence. A distinct idea of the nature of an Eisteddvod may be most readily obtained by observing the proceedings at one of the most successful of them—that held at Llangollen in the autumnal equinox of 1858. The meeting took place at the equinox, in obedience to alleged bardic custom, and was consequently rather too late in the year, so that there were several days of rain. A pavilion was erected on the bowling-green adjacent to the Ponsonby Arms Hotel, at Llangollen, so spacious as to be capable of containing five thousand persons; and at the last meeting it is stated that this pavilion was "literally crammed, with such an assembly as was scarcely, if ever, witnessed in the Principality." On the first day the proceedings commenced with a procession of Bards, Druids, Ovates, and others, with the members of the three orders attired in their distinctive costumes—the bards in a loose habit of blue, the druids in snowy white, and the ovates in green. The procession led to a spot where three hugh stones were placed in the order /|\. "These lines, or pencils of light, as they are termed, form," we are told in the Report, "the mystic symbol known amongst the bards and druids as the name of God—the 'Word' or attribute of creation—it being held by the bards that God created the universe by showing and pronouncing His own name." It will be remembered that seventy years ago this tradition, such as it is, was unheard-of in Wales, and only existed in an unpublished manuscript. The Rev. John Williams ab Ithel, presiding bard of the Eisteddvod, stood on the central stone within a circle, and delivered an address, received with "frequent marks of applause," to the effect that the Cymry succeeded beyond all other nations in keeping the ancient religion of Noah uncorrupted till the coming of the Messiah, when "they received the Gospel as the superstructure or completion of Druidism, and their ancient system was clothed with Christianity." A ceremony then took place of receiving and admitting candidates for the orders of bards, druids, and ovates. In the course of the day, speeches were delivered, and various essays were read which had been determined to be the best sent in to compete for prizes. One of these prizes was of twenty-five pounds, offered by the young men of Llangollen, for the best treatise on the mineral resources of Wales, with the stipulation that if the successful composition should be in English, it should be translated into Welsh at the author's expense. The prize was adjudged to an essay signed "Didascalos;" and the author being called for, appeared in the person of the Rev. John Jones, Baptist minister of Llangollen, who was publicly presented with the prize by Miss Williams ab Ithel. The proceedings of the day terminated with a concert, at which about three thousand persons attended, to admire Mr. Ellis Roberts's performance on the harp, laugh at Owen Alaw's comic song of "Hen Forgan a' i Wraig" (Old Morgan and his Wife), and enjoy similar festivities. On the second day, an English gentleman, Mr. Kenward, recited some lines of a poem on 'English Sympathy with Wales;' but, say the reporters, "a feeling of impatience being manifested by the Welsh portion of the audience who did not understand English, Mr. Kenward, felt reluctant to read the whole, and retired from the platform." Another English gentleman remonstrated, and Ab Ithel came forward to inform the meeting that Mr. Kenward was a person who pre-eminently "loved our nation," and had been most indefatigable in collecting subscriptions for the Eisteddvod, on which he was allowed to proceed through about twenty stanzas. More speeches and Pennillion singing followed, and an adjudication of the prize of 30*l.* for an Ode in Welsh on "the Battle of Bosworth Field, by which the Cymry recovered the monarchy of the isle of Britain." On another day the main feature was the presentation of a "Cambrian gold torque of valour" to Corporal Shields, of the Welsh Fusileers, who had fought in the Crimea. Close to Llangollen, on the summit of a hill, are the ruins of Dinas Bran, a name sometimes translated "Crow's Castle," Bran being the Welsh word for "crow," but supposed to take its origin from the mountain-torrent, Bran, which runs beneath. Some antiquaries have absurdly supposed the castle to be named after Brennus, king of the Gauls, and the Rev. R. W. Morgan, in presenting the torque, took occasion to mention it thus: "Corporal Shields is a Cymro, the representative of a race that from the earliest ages has been distinguished by two grand characteristics—profound religious feeling, and chivalry in the field. Towering above us, frown the ruins of the castle of one of the earliest of the great conquerors of mankind, Brân or Brennus, the captor of the Eternal City, the founder of the Cisalpine empire and its civilisation, the first general that, long antecedent to Hannibal, crossed the glaciers and snows of the Alps, and vanquished the opposing bulwarks of Nature herself. (Loud cheers.)" Choral singing, contentions with the harp, impromptu poetical contests, recitations of the speech of Caractacus by boys, competitions of the best female singers to the harp, and the best female harpists, filled up the remainder of the four days during which the Eisteddvod lasted, each day concluding with a concert. The devotion to the charms of poetry and music, which was shown by so large a population, many of the peasant class, was certainly a high mark of civilisation and refinement of character; but the patriotism of many of the speeches was of the spurious kind, which is as ready to boast of the false as the true, and the semi-religious character of many of the proceedings presented still graver matter of objection. There seems too much resemblance between the adherents of the Book of Llewelyn Sion of Llangewyd and the believers in the Book of Mormon, who are unhappily numerous in Wales.

One speech at an Eisteddvod, of a different character from those usually delivered, contains some remarks which, though expressed in rough and homely terms, it would be well for Cymric patriots to consider. They occur in the Welsh portion of the works of the modern Talhaiarn, in the report of a speech delivered at an Eisteddvod at Llanfairtalhaiarn:—"It is the greatest folly in us to shout out that we are at the head of the world in poetry and prose. It is a very great mistake; for the fact is the Saxons beat us all to pieces in poetry, philosophy, and all kinds of learning. Do you think I say this to hurt or insult my country or my nation? Nothing of the kind. I reverence and love them both, nor will I ever go about to seek to find fault with either. Neither will I soil my lips with an untruth to please any man, nor will I do an injustice to my neighbour by boasting of what is really nothing to boast of. If you could all read Shakspeare, Milton, Byron, and Burns, the 'Times,' and 'Blackwood's Magazine,' and some other authors, magazines, and newspapers, you would all believe with me that the Saxons are much our superiors. Well, you will say, and have not we a literature? Yes, most certainly, and an excellent literature too, considering that Wales is but a little corner of the world. My only purpose was to wean you from the silly boast that we are at the head of the world in literature; there never was such nonsense."

The formation of a library of ancient Welsh manuscripts on a liberal and extensive scale in the possession of a public establishment appears an object greatly to be desired. The history of the fate of Welsh manuscripts during the last two centuries affords ample proof of the danger to collections of this kind in private hands, to say nothing of the fact that in many cases all access to the manuscripts has been denied to the very men, such as Lhuyd, who would have made the best use of them, and that in all cases there is necessarily a delicacy of intruding on the courtesy of a private proprietor. The number of libraries destroyed by fire has been unusually large in the case of the country gentlemen of Wales. The collection of transcripts by Lhuyd, which, after his death, was unfortunately declined both by the University of Oxford and by Jesus College, passed into the hands of Sir Thomas Sebright, by purchase, and was long afterwards divided by sale between the libraries of Hafod and Wynnstay. The portion in the splendid collection of Colonel Johnes, at Hafod, perished with that collection in the fire of 1807. The portion belonging to the Wynnes was almost entirely destroyed by a fire at a bookbinder's in London, and the conflagration of Wynnstay itself, in 1858, probably consumed the remainder, as on that occasion only the books that had been casually sent to a bookbinder's in London were saved. In the preface to the 'Myvyrian Archaiology' is given a list of the libraries public and private in Wales, London, and Oxford, in which valuable Welsh collections were preserved, amounting to twenty-five in number. Four of these libraries were in London, that of the British Museum, of the Welsh School, in Gray's Inn Lane, of Mr. Owen Jones, the originator of the 'Myvyrian Archaiology,' and of Mr. Edward Jones, author of the 'Relics of British Bards.' Three of these are now united, the collections of the Welsh School and Owen Jones having been presented to the British Museum in 1843. These books are thus preserved in one collection under public care, and it would be most conducive to the interests of literature if others were to follow. Some of the perpetual disputes about the accuracy of the transcripts of Iolo Morganwg which agitate Welsh literature might be settled at once if the 'Book of Aberpergwm' were in a collection where any one might examine it. It is stated in the 'Myvyrian Archaiology,' in 1801, that the editors had some hope that the Earl of Macclesfield would deposit in the Museum the collection of manuscripts made by the learned Moses Williams, and which Williams had bequeathed to Mr. Jones, father of the celebrated Sir William Jones, who bequeathed them to the then Earl of Macclesfield, with the singular injunction not to show them to any person whatever. These manuscripts however are still in the possession of the noble family of Macclesfield. The famous library of the Vaughans, at Hengwrt, in Merionethshire, is now united with the collection of Mr. W. E. Wynne, of Peniarth, M.P., for Merioneth, to whom it was bequeathed by his friend the late Sir R. W. Vaughan.

There is no collection of Welsh printed books approaching to completeness, the best in existence being probably that in the British Museum, which contains an assemblage of magazines and newspapers in that language, to which, though far from perfect, it would be difficult to find a rival. Welsh books were first collected at the Museum, about the year 1838, and the presentation of the libraries of the Welsh School, and the Cymmrodorion in 1843 made some augmentation to the stock. Another Welsh collection of some extent is to be found where it would scarcely be looked for, in the library of Brown University, at Providence, in Rhode Island, to which it was bequeathed in 1818 by the Rev. William Richards, of Lynn, in Norfolk. The books are enumerated in the excellent catalogue of that library published by Professor Jewett.

The bibliography of Wales was first cultivated by the Rev. Moses Williams, the able and indefatigable antiquary, who has been mentioned as having nearly anticipated the 'Myvyrian Archaiology.' Owen says of him, in his 'Cambrian Biography,' that "he published nothing of consequence besides an index to the Welsh poets," but in this he is mistaken. In addition to the 'Repertorium Poeticum, sive Poematum Wallicorum, quotquot hactenus videre contigit Index Alphabeticus' (London, 1726, 8vo), which contains an index of pieces of Welsh poetry, according to their first lines, and the fullest catalogue of poets we have seen, Williams issued a 'Cofrestr o'r holl Lyfrau Printiedig gan mwyaf a gyfansoddwyd yn y Jaith Gymraeg, neu a gyfjeithwyd iddi, hyd y Flwyddyn 1717' (London, 1717, 8vo)—'A catalogue of all the books that have been printed, and several that have been composed, in the Welsh Language, or translated into it, up to the year 1717.' This catalogue does not extend to more than a single sheet, but it is very closely printed. The original edition is now very scarce, but the whole of it was reprinted in the periodical entitled 'Y Gwyliedydd,' for 1832. In the 'Gwladgarwr' for 1840 a list of Welsh publications is given, from the earliest time to the year 1799; but, though valuable, it is probably very imperfect, as it omits even some of the works inserted in Williams's catalogue. The number of articles it enumerates is 620, but these include a few works relating to Wales in other languages than the Welsh. In the volume of the 'Traethodydd' for 1852, was commenced a valuable series of articles on Welsh bibliography, 'Llyfryddiaeth y Cymry,' containing not only the titles of the books but bibliographical notes and observations, but it was not continued so long as bibliographers would have desired. A work of the same kind in English, from the pen of the Rev. Robert Jones, of Rotherhithe, a scholar eminently qualified for the task, was spoken of some time ago, but has not yet appeared. A very useful bibliographical list of works on Wales and its literature is to be found in the German work, 'Das alte Wales,' (Bonn, 1859) by Ferdinand Walter, a continental scholar who has lately studied the subject with German diligence. A bibliographical periodical intended to be quarterly, 'The Cambrian Book Register,' was commenced in June, 1857, by Mr. Pryse, a bookseller of Llanidloes and Rhayader, but never advanced we believe beyond the first number.

The earliest attempt at a collection of Welsh lives is Owen Pughe's 'Cambrian Biography, or Historical Notices of celebrated men among the Ancient Britons' (London, 1803, 12mo), but the notices are so extremely brief, averaging four or five to a page, that the book can hardly be regarded in any other light than an index. The dates are also very far from accurate. The 'Cambrian Plutarch' of John Humffreys Parry (London, 1824, 8vo), is much more satisfactory, but embraces only twenty-two lives. A biographical dictionary under the name of 'Lives of Eminent Welshmen,' was commenced in numbers in 1843 and completed in 1852, by the Rev. Robert Williams of Llangadwaladr. The articles are too brief, and not so entertaining as they might have been made by the use of the materials existing in Welsh; but the volume is indispensable in every Welsh library, and one to which we have been much indebted in this general summary of the history of Welsh literature.

WEN, the name of those tumours occurring on the human body which assume the form of a bag or cyst, and contain a variety of contents. These cysts have been named according to the character of their contents. When the contained matter resembles fat or suet, the tumor is called *Steatoma;* when it resembles honey in consistence, *Meliceris;* and when it is like a poultice or pap, it is called *Atheroma*. These however are mere artificial distinctions, and can seldom be satisfactorily applied. These tumours consist essentially of a serous or mucous bag varying in size, and the contents are of an exceedingly varying and sometimes anomalous character. Those which are commonly called wens, and which are usually situated immediately under the skin, are mostly enlargements of the sebaceous follicles which naturally exist in the skin. Sir Astley Cooper says that in wens a dark-coloured spot may be often seen on the skin in the centre of the tumour, and such spot, he says, is caused by the construction of the orifice of one of the sebaceous glands of the skin. Such also is the origin of many of the cysts of the mammæ, which consist of dilated lactiferous ducts. But this is not the origin of many of the larger forms of encysted tumours, as those of the ovary, &c. There are many forms of encysted tumour occurring in the internal viscera, in which the lining membrane is composed of serous tissue, as those of the liver, lungs, &c. Those tumours also called ganglions, which occur within the sheaths of tendons, have a serous lining, but ought not to be referred to under the character of wens.

The cysts of wens, especially those of the atheromatous kind, vary much in thickness. When situated on the head, back, and trunk, they are very dense; but when on the face, often very thin. Sometimes the cysts become hardened by the deposition of cartilaginous and even ossific matter. It is from this process that many of these cysts have a tendency to assume the hardness and even the form of horns. These horny formations are however the result of the ulceration of the cyst, and the horny matter is produced by the secretion from the walls of the cyst. These horns mostly grow on the forehead or some part of the scalp. They are generally small, but instances are on record of their being eight or nine inches long and two or three in circumference.

In ordinary cases the cyst has only one cavity, but it not unfrequently happens that there are partitions in it, dividing its interior into cells of different sizes. The contents of the cysts are, as before stated, frequently very anomalous. Some are filled with a thin, fetid brown fluid, mixed with flakes of the fibrinous parts of the blood; some contain serum; some a matter of gelatinous consistence; some a calcareous matter; some a black fluid; and others hair, teeth, and other organic substances. Those containing hair are mostly found in the neighbourhood of the eyebrows or eyelids.

On dissecting these tumours, some part of their surface is found firmly adhering to the skin, while other parts are connected with it by cellular membrane. The cyst is always more or less embedded in cellular membrane. In some cases these cysts are congenital and persons who have them are frequently troubled with a great number in various parts of their body.

In the treatment of wens two modes may be had recourse to; the one by puncture, the other by removal. When the cyst is small and presents a small black point on its centre, it may be opened and the contents pressed out, when it will sometimes get well. But it frequently happens when these tumours are punctured, that severe inflammatory action is the result, so that painful suppuration occurs, and life is put in danger, and sometimes a bleeding fungus has protruded itself through the aperture. The safest mode of treatment in the whole is to remove them with the knife, where their situation will permit of it. When this is done, the cyst may either be dissected out entire, or it may be cut into two halves, and each half may be dissected out separately. In both cases great care should be taken to remove the whole of the cyst.

WERST, or **VERST**, the Russian itinerary measure, being 3500 English feet, or nearly two-thirds of a mile. From the number of wersts subtract its third, and also one for every 250 wersts, and the result will be near enough to the answer in English miles.

WESTMINSTER ASSEMBLY OF DIVINES. One of five bills to which it was proposed by the Parliamentary Commissioners that the King (Charles I.) should give his consent in the negotiations at Oxford (from 30th January to 17th April, 1643) was entitled 'A Bill for calling an Assembly of learned and godly Divines and others to be consulted with by the Parliament for the settling of the government and liturgy of the Church of England, and for the vindication and clearing of the doctrine of the said church from false aspersions and interpretations.' This bill was afterwards converted into 'An Ordinance of the Lords and Commons in Parliament,' and passed 12th June, 1643.

The persons nominated in the ordinance to constitute the assembly consisted of a hundred and twenty-one clergymen, together with ten lords and twenty commoners as lay assessors. Among the commoners were John Selden, Francis Rouse, Sir Henry Vane, senior and junior, John Glynn (the recorder of London), John Whyte, Bulstrode Whitelock, Sergeant Wild, Oliver St. John, John Pym, and John Maynard. Among the most distinguished of the clerical members were, Dr. Ralph Brownrigge, bishop of Exeter; Mr. Anthony Burges (considered the head of the Puritans), Edmund Calamy, Dr. Francis Cheynel, Thomas Coleman, Thomas Gataker (the editor of 'Marcus Antoninus'), Dr. Thomas Goodwin, Dr. John Hacket (afterwards bishop of Lichfield), Dr. John Lightfoot, Dr. George Morley (afterwards bishop of Winchester), Dr. William Nicholson (afterwards bishop of Gloucester), Philip Nye, Dr. John Prideaux (bishop of Worcester), Dr. Edward Reynolds (afterwards bishop of Norwich), Dr. Robert Saunderson (afterwards bishop of Lincoln), Dr. James Usher (archbishop of Armagh), George Walker, Dr. Samuel Ward, and John Wallis (the mathematician). Several other persons (about twenty in all) were appointed by the Parliament from time to time to supply vacancies occasioned by death, secession, or otherwise, who were called superadded divines. Finally, two lay assessors, John Lord Maitland and Sir Archibald Johnson of Warriston, and four ministers, Alexander Henderson and George Gillespie of Edinburgh, Samuel Rutherford of St. Andrews, and Robert Baillie of Glasgow, were, on the 15th of September, 1643, admitted to seats and votes in the assembly by a warrant from the Parliament as commissioners from the Church of Scotland. They had been deputed by the General Assembly, to which body, and to the Scottish Convention of Estates, commissioners had been sent from the two houses of the English Parliament, and also from the Assembly of Divines, soliciting a union in the circumstances in which they were placed. This negotiation between the supreme civil and ecclesiastical authorities of the two countries gave rise to the Solemn League and Covenant, which was drawn up by Henderson, moderator (or president) of the General Assembly, and, having been adopted by a unanimous vote of that body on the 17th of August, was then forwarded to the English Parliament and the Assembly of Divines at Westminster for their consideration.

The meeting of the Assembly of Divines had been forbidden by the king in a proclamation dated the 22nd of June. The only effect however of that prohibition had been to induce the greater number of the members of episcopalian principles to refrain from attending. On Saturday, the 1st of July, the day named in the ordinance, sixty-nine clerical members assembled in Henry the Seventh's chapel, in Westminster Abbey. They appeared, it is recorded, not in their canonical habits, but mostly, after the fashion of foreign Protestant clergymen, in black coats and bands. At subsequent sittings the attendance appears to have ranged between sixty and eighty. About twenty-five of the persons who had been nominated members of the Assembly (including one or two who had died) never took their seats; and even of the sixty or seventy who attended pretty regularly, only from twelve to twenty were frequent speakers.

In theological doctrine the divines of the Westminster Assembly were almost to a man of one mind. They were all, or nearly all, Calvinistic or anti-Arminian. But upon the subject of church government they were divided into several violently hostile sections. Episcopacy, even of the most mitigated kind, could scarcely be said to have any representative in the synod as actually constituted; the great majority were Presbyterians; but there was a small party who passed under the name of Erastians; and there was a more numerous and also a more active body of Independents, or, as they called themselves, Congregationalists, who, formidable from the perseverance and ability of their leaders, were still more so from the ascendancy which their principles were fast acquiring in the Parliament, in the army, and throughout the nation. The chiefs of the Independent party in the Assembly were Dr. Thomas Goodwin, Philip Nye, Jeremiah Burroughs, William Bridge, and Sidrach Simpson, often spoken of as the Five Dissenting Brethren: their followers might amount to about as many more. The heads of the Erastian party were Selden, and the two divines, Lightfoot and Thomas Coleman; the only other steady members of the sect being the laymen Whitelock and St. John. In the Parliament however Erastianism was nearly as strong as Independency: indeed, however much the two systems might differ in the grounds on which they professed to stand, they came practically to very nearly the same thing, or at least were easily reconcileable; and some persons were probably to be classed as adherents of both.

This position of parties explains and makes intelligible the history of the proceedings of the Westminster Assembly, and the results of its deliberations. The ordinance of the Lords and Commons by which the Assembly was constituted only authorised the members, until further order should be taken by the two houses, "to confer and treat among themselves of such matters and things touching and concerning the Liturgy, discipline, and government of the Church of England, or the vindicating and clearing of the doctrine of the same," &c. as should be "proposed to them by both or either of the said houses of Parliament, and no other," and to deliver their opinions and advices to the said houses from time to time in such manner and sort as by the said houses should be required. They were not empowered to enact or settle anything. It was expressly provided that the Assembly should not assume to exercise any jurisdiction, power, or authority ecclesiastical whatsoever, or any other power except merely this right of delivering their opinion and advice upon the matters submitted to it. As its discussions proceeded, a discordance of principles and views upon various points between the ruling Presbyterian party in the Assembly and the growing Independent or Erastian majority in the Parliament became more and more evident; while the progress of events also tended to separate the two bodies more widely every day, and at last to place them almost in opposition and hostility to each other. The Assembly of Divines continued to sit under that name till the 22nd of February, 1649, having existed five years, six months, and twenty-two days, during which time it had met 1163 times. The Scottish commissioners had left above a year and a half before. Those of the members who remained in town were then changed by an ordinance of the Parliament into a committee for trying and examining ministers, and continued to hold meetings for this purpose every Thursday morning till Cromwell's dissolution of the Long Parliament, 25th of March, 1652, after which they never met again.

All the important work of the Assembly was performed in the first three or four years of its existence. On the 12th of October, 1643, the Parliament sent them an order directing that they should "forthwith confer and treat among themselves of such a discipline and government as may be most agreeable to God's holy word, and most apt to procure and preserve the peace of the church at home, and nearer agreement with the Church of Scotland and other Reformed churches abroad, to be settled in this church in stead and place of the present church government by archbishops, bishops, &c., which is resolved to be taken away; and touching and concerning the directory of worship or Liturgy hereafter to be in the church." This order produced the Assembly's Directory for Public Worship, which was submitted to parliament on the 20th of April, 1644; and their Confession of Faith, the first part of which was laid before Parliament in the beginning of October, 1646, and the remainder on the 26th of November in the same year. Their Shorter Catechism was presented to the House of Commons on the 5th of November, 1647; their Larger Catechism on the 15th of September, 1648. The other publications of the Assembly were only of temporary importance, such as admonitory addresses to the Parliament and the nation, letters to foreign churches, and some controversial tracts. What are called their Annotations on the Bible did not proceed from the Assembly at all, but from several members of the Assembly and other clergymen nominated by a committee of Parliament, to whom the business had been entrusted.

The Directory of Public Worship was approved of and ratified by the General Assembly of the Church of Scotland held at Edinburgh in February, 1645; the Confession of Faith, by that held in August, 1647; the Larger and Shorter Catechisms, by that held in July, 1648; and these formularies still continue to constitute the authorised standards of that establishment. The Directory of Public Worship was also ratified by both houses of the English Parliament on the 2nd of October, 1644; and so was the doctrinal part of the Confession of Faith, with some slight verbal alterations, in March, 1648. On the 13th of October, 1647, the House of Commons passed an order that the Presbyterian form of church government should be tried for a year; but it was never conclusively established in England by legislative authority; and even what was done by the parliament in partial confirmation of the proposals of the Westminster Assembly of Divines, having been done without the royal assent, was all regarded as of no validity at the Restoration, upon which event episcopacy resumed its authority without any act being passed to that effect.

It is remarkable that there is not in existence, as far as is known, any complete account of the proceedings of the Westminster Assembly of Divines, either printed or in manuscript. The official record is commonly supposed to have perished in the fire of London. Three volumes of notes by Dr. Thomas Goodwin are preserved in Dr. Williams's Library, London; and two volumes by George Gillespie in the Advocates' Library, Edinburgh. Baillie's Letters, however, contain very full details of what was done during the period of his attendance; and a Journal kept by Lightfoot has also been printed. Much information is to be found scattered in various works, such as Reid's 'Memoirs of the Westminster Divines;' Orme's 'Life of Owen;' and especially Neal's 'History of the Puritans.'

WESTPHALIA, TREATY OF. [TREATIES, CHRONOLOGICAL TABLE OF.]

WEY. [WEIGHTS AND MEASURES.]

WHALE FISHING. [FISHERIES.]

WHALEBONE is the horny laminated substance found in the mouth of the whale. It is not really whale-*bone*, but bears a nearer resemblance to horn in its structure: in commerce it is usually termed *whale-fin*. There are in the mouth of a whale two extensive rows, each consisting of upwards of 300 blades or plates; and each of these blades is a piece of whalebone. The blades are on an average about 10 feet long, but some attain a length of 15 feet. The substance is naturally of a bluish or brownish-black; but in some animals it is striped longitudinally with white. Three principal kinds are known in commerce—the Greenland whalebone, from the North Atlantic and Icy Seas; the South Sea, or black fish; and the North-West, from the North Pacific and Behring's Straits. [CETACEA, cols. 895–98, in NAT. HIST. DIV.] Sometimes as much as 5,000,000 lbs. have been imported in one year; but the supply is generally from 2,000,000 to 3,000,000 lbs. All the kinds of whalebone are nearly alike in constitution. It consists chiefly of albumen hardened by a small proportion of phosphate of lime. The surface of each blade is compact, and takes a high polish. The texture is lamellar or fibrous in the direction of its length, so that the substance easily splits and divides. The middle of each blade is of looser texture than the ends, presenting the appearance of coarse bristly hairs. When whalebone has been boiled, it takes a harder texture and deeper colour than before.

The peculiar structure of whalebone renders it applicable to many useful purposes. It is cut into quadrangular sticks for the ribs or stretchers of umbrellas and parasols, ranging in length from 20 to 40 inches. It is made into stay-bones, from $\frac{5}{16}$ths to $1\frac{3}{4}$ inch in width, and from 12 to 16 inches long. It is cut into lengths of what is called bristle-bone, of different thicknesses, for making brushes and brooms, chimney-sweeping machines, and road-sweeping machines. It is used in thin strips for covering whip-handles, walking-sticks, telescopes, and other articles. In thinner shavings it is plaited like straw into light hats and bonnets; while the waste shavings are employed by upholsterers as a stuffing for cushions, for filling fire-grates in summer, and for other purposes. Occasionally solid pieces of mixed tints are twisted into walking-sticks. And when all the useful fragments have been rendered available, the refuse sells as manure.

The nature of whalebone, something midway between horn and hair, points to the mode in which it is worked. It cannot be soldered or joined like tortoiseshell, but must be used in distinct pieces. When boiled in water for several hours, it becomes soft enough to be cut up into pieces of various sizes and shapes. Without being heated and softened, it is easily cut into strips and fibres by means of a compound guarded knife. The different qualities in different parts of each blade are closely examined by the workmen, in order to apply each part to the best use. Whalebone takes a very good jet-black dye, but is not well fitted for dyeing in bright colours. It is generally polished by being scraped with a steel edge or a piece of glass, rubbed with emery-paper, and finally rubbed with a woollen cloth dipped in tripoli powder; or by a polishing-wheel, as in the case of horn or tortoiseshell.

Common horn, if steeped for several days in a solution of gelatine, and then in a liquid containing several ingredients, acquires properties which enable it to be used for some purposes as a cheap substitute for whalebone.

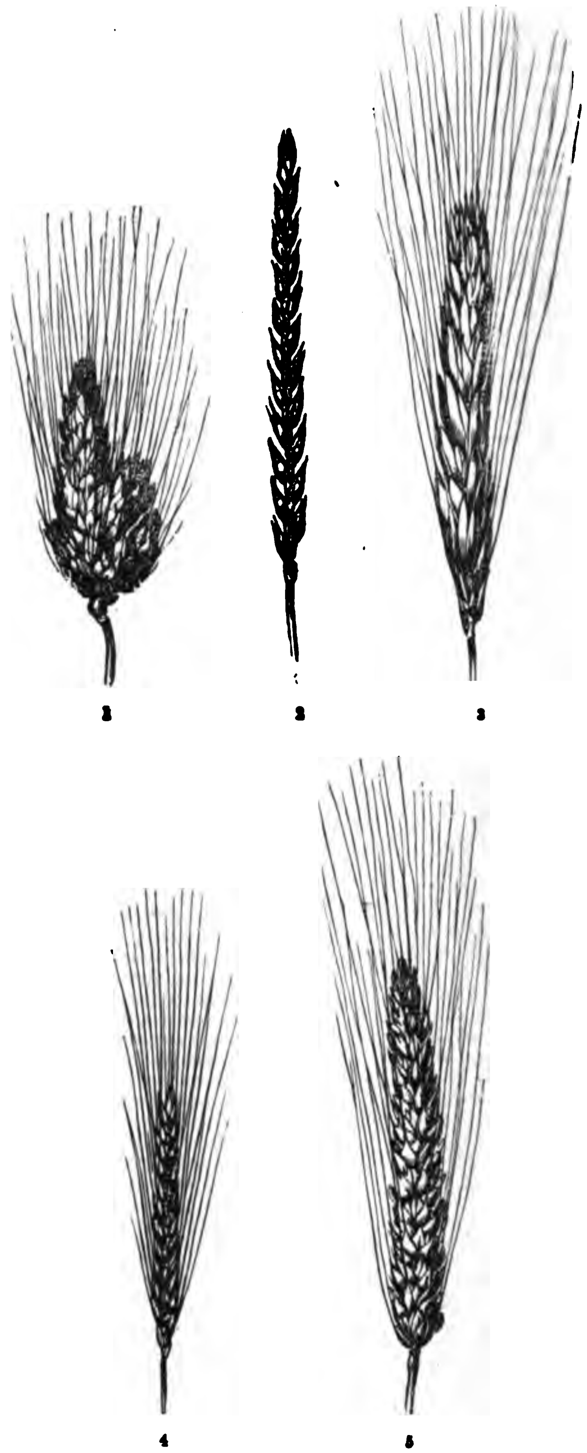
WHARF, a place constructed or set apart for the loading and unloading of goods. In this sense the word includes the quays of all sea-ports at which goods are required to be shipped or landed. The sea-beach, or natural ground on the banks of a river or canal, is not a wharf. Wharfs in docks and similar situations are made legal by special acts of parliament, as the London Docks, &c.; and there are some places which are deemed wharfs from immemorial usage, as at Chepstow. For the use of a wharf certain rates of compensation are usually charged, which are called *wharfage*; and the act 22 Car. II., c. 11, allows any one to load or unload goods on paying wharfage at the rates appointed. The wharfs of the port of London were established in 1558, in the first year of the reign of Queen Elizabeth. Several *sufferance wharfs* have been since added to these, under the authority of the Commissioners of Customs, and other sufferance wharfs are occasionally authorised for the landing and keeping of goods by the Custom-House till the duties are paid or the goods bonded.

No goods except diamonds and bullion, fresh fish of British taking, and turbots and lobsters fresh, however taken or imported, are allowed to be unshipped from any ship arriving from foreign parts beyond seas, or landed or put on shore, except at legal quays appointed by her Majesty for landing of goods, or at some wharf appointed by the Commissioners of Customs. Goods entitled to drawback or bounty are only to be shipped in Great Britain by wharfingers appointed by the Commissioners of Customs.

WHEAT. The botanical characters of wheat will be found under the word TRITICUM, in NAT. HIST. DIV. Some botanists have divided wheats into different species, from some marked peculiarity in their formation. Others, considering that they mostly form hybrids when mixed in the sowing, and that their peculiarities vary with the soil and climate, have looked upon all the cultivated wheats as mere varieties. There are, however, three principal varieties, so different in appearance that they claim peculiar attention. These are the hard wheats, the soft wheats, and the Polish wheats. The hard wheats are the produce of warm climates, such as Italy, Sicily, and Barbary. The soft wheats grow in the northern parts of Europe, as in Belgium, England, Denmark, and Sweden. The Polish wheats grow in the country from which they derive their name, and are also hard wheats. It is from their external form that they are distinguished from other wheats. The hard wheats have a compact seed nearly transparent, which, when bitten through, breaks short, and shows a very white flour within. The soft wheats are those usually cultivated in Britain: they have an opaque coat or skin, which, when first reaped, gives way readily to the pressure of the finger and thumb. These wheats require to be well dried and hardened before they can be conveniently ground into flour. The Polish wheat has a long chaff which is much longer than the seed, a large oblong hard seed, and an ear cylindrical in appearance. It is a delicate spring wheat, and not very productive in the climate of England: hence it has only been occasionally cultivated by way of experiment.

The following cuts represent some peculiar varieties of wheat. The first is a compound ear, common in Egypt. The second is the spelter wheat, of which the chaff is so strongly attached to the grain as to be separated only by passing through a mill. It is an inferior variety, but grows in less fertile soils. The third is the Polish wheat, with very long chaff and hard grains. The fourth is a variety which only ripens one seed in each spikelet, and is not much cultivated. The fifth is common soft bearded wheat. If the awns of this kind are obliterated, it forms our common soft wheat. The circumstance of awns seems not to affect the nature of the wheat, and they differ so much in length that the varieties of smooth-eared and bearded wheats run insensibly into each other.

The distinction between the winter and summer wheats is one which arises entirely from the season in which they have been usually sown; for they can readily be converted into each other by sowing earlier or later, and gradually accelerating or retarding their growths. The original difference in colour between red and white wheats is owing chiefly to the soil: white wheats gradually become darker and ultimately red in some stiff wet soils, and the red wheats lose their colour and become first yellow and then white on rich, light, and mellow soils. It is remarkable that the grain sooner changes colour than the chaff and straw. Hence we have red wheats with white chaff, and white wheats with red chaff, which on the foregoing principle is readily accounted for. The chaff retains the original colour when the skin of the grain has already changed to another. We state this on our own experience. The soil best adapted to the growth of wheat is a deep loam inclined to clay, with a dry subsoil. If this is not dry naturally, it must be drained artificially, to ensure good crops of wheat. In such a soil wheat may be sown every third year, with proper intermediate crops. Formerly the preparation for a wheat crop was generally by a clean naked fallow, with a certain addition of manure, the remains of which were thought sufficient for a crop of barley or oats, after which the fallow recurred. It was soon found out that by this means a crop of wheat could never be forced beyond a certain average; for if more than the usual portion of manure was carried on the land the wheat failed, by being laid before it arrived at maturity. Thus a limit appeared to have been set to its increase. New modes of cultivation have shown that this was not without its remedy, and that it was recent manuring which caused the wheat to lodge: but that an increased fertility, produced by judicious preparation, enabled the land to bear crops of wheat far superior to what it ever could before. Wheat requires a soil in which the organic matter is intimately mixed



1. Egyptian Wheat (Triticum Egyptiacum); 2, Spelter Wheat (Triticum Spelta); 3, Long-chaffed Polish Wheat (Triticum Polonicum); 4, Single-grained Wheat (Triticum monococcum); 5, Common Bearded Wheat (Triticum turgidum).

with the earthy ingredients; where it can have a firm hold by its roots, and can at the same time strike the fibres of them downwards, as well as around, in search of food. When it meets with such a soil and is deposited at a proper depth, it vegetates slowly, pushing to the surface one cylindrical filament, while numerous fibres strike into the soil from the seed. These supply the plant with regular nourishment, and in due time a knot is formed at the surface of the soil, from which several roots and stems branch out. This is called the tillering of the wheat. The new roots near the surface soon become the chief source of nourishment, and in a rich compact soil, where there is room, numerous stems arise, forming a tuft, and each of these in time bears a large ear well filled with seeds; so that from a very moderate quantity of seed a great return is produced. The strong stems supporting each other are well able to resist the effect of storms and rains, which would lay weaker plants level with the ground. The effect of surface manuring immediately before the seed is sown is to produce too rapid a growth, weakening the straw, and increasing its quantity often at the expense of the ear, which does not attain its proper development. This is called running to straw. Ammoniacal and nitrogenous manures have this effect; which is corroborated by late experiments with sulphate of ammonia, saltpetre, and nitrate of soda.

Lime has been often considered as the most efficacious manure for wheat, even more than dung. As long as there is organic matter in the soil, lime acts beneficially, and the richer the land, which does not contain carbonate of lime already, the more powerful the effect of liming. But experience has proved that lime has little effect on poor soils, until they are first manured with animal and vegetable substances. To produce good wheat then, the land should be gradually brought to the proper degree of fertility, by abundant manuring for preparatory crops, which will not suffer from an over-dose of dung, and will leave in the soil a sufficient quantity of humus, intimately blended with it, for a crop of wheat. Clover is a plant which will bear a considerable forcing, and so are beans, and both are an excellent preparation for wheat. The roots left in the ground from a good crop of either, decay slowly, and thus furnish a regular supply of food for the wheat sown in the next season. Potatoes also admit of much forcing, but the necessary loosening of the soil for this crop renders it less fit as a preparation for wheat. Experience has fully proved that, as a general rule, it is better to sow barley and clover after potatoes, and let them be succeeded by wheat.

Although wheat thrives best on heavy soils, and without due preparation produces only scanty and uncertain crops in those which are naturally light and loose, it may be made to give a very good return in soils which would once have been thought fitted only for the growth of rye and oats. But then the texture and composition of these soils must have been greatly improved by judicious tillage and manuring. While the heavy soils are repeatedly ploughed and pulverised to render them mellow, the lighter are rendered more compact by marling, where this can be readily done, by adding composts in which the principal earth is clay, and especially by such plants as have substantial and long roots, by which the soil is kept together, such as clover, lucern, sainfoin, and other grasses. If these plants have been well manured, and cover the ground well, keeping in the moisture, the soil will have become sufficiently compact to bear wheat. One ploughing is then quite sufficient, and if a heavy land-presser is made to follow two ploughs and press in the furrows, so as to leave deep smooth drills eight or nine inches apart, in which seed can find a solid bed, there will be every probability of a good crop, of wheat, which will come up in regular rows, the roots being at such a depth as to run no risk of wanting moisture till the stem has arisen to its full height, and the ear is formed: a few showers at that critical time will make the grain swell, and insure a good crop.

On some soils it may not be judicious to attempt to sow wheat; but these are the poorest loose sands, which naturally would bear only oats and buckwheat; on these, unless they can be abundantly marled, it is much better to sow rye. When wheat is sown on light soils in good heart, it grows vigorously in spring, if it has not been injured by the frost, which is very apt to raise up the roots and throw them out of the ground. The driving of sheep over the field presses the roots into the ground, and prevents this throwing out; but a vigorous growth of straw is not always a sure sign of a good crop at harvest, as many farmers know by sad experience: what would be advisable in heavy soils is not always so in lighter. A heavy rolling in spring after a light harrowing is very useful at a time when the surface is moist. It closes the pores and checks the evaporation: and the tighter the surface can be made the better the chance there is of a fair crop. The Norfolk rotation, as it is generally called, in which wheat is sown after clover, is the only one well adapted for wheat on light soils. The manure having been put abundantly for the turnips, and the land being freed from weeds, the barley which follows is generally a good crop; the clover, which is sown in this, is trodden in the reaping and carrying of the barley: and there is only one ploughing from the time the barley is sown to the sowing of the wheat. If this be dibbled on the turned sward of the clover, the land will receive another treading by the dibblers, the seed will be regularly deposited at a proper depth, and no preparation of light land can be more likely to produce good wheat. On heavy soils the process must be varied; the surface, instead of being rendered more compact, will often be so bound as to require to be stirred by harrowing or hoeing before the wheat plant can properly tiller. If a farmer is anxious to have good crops of wheat, he must not rest satisfied after he has ploughed, manured, and sown: he must watch the growth of this important crop daily, and use the means which experience and observation have suggested to assist the growth and to remove the causes of failure.

In either case it is of importance to sow the proper quantity of seed per acre in rows far enough apart. One bushel per acre is enough on well-cultivated soils—two bushels are not too much where there is liability to loss by water, wireworm, and weather. If sown by drill from 10 to 12 inches is a proper interval between the rows.

In heavy soils nothing is more detrimental than excess of moisture. Even in well-drained fields the water will stand too long in the furrows if there is not a proper outlet for it. The furrows should be well cleared out with the spade as soon as the seed is sown, drilled, or dibbled, the earth being thrown evenly over the surface of the stitches, and not left in an unsightly ridge, which crumbles down with the furrow at the first frost. In proper places and at regular distances deeper water furrows should be dug out after the plough has ploughed a deep furrow in the intended line; and this should then be finished as is said above: so that if a heavy fall of rain should come suddenly, the water would have a regular course and outlet into the ditches which lie in the lowest part of the land, without soaking into the soil, which is already too retentive of moisture. It is chiefly in spring and when snow melts that there should be a daily inspection of the wheat-field. An experienced eye going along the bottom of the ridges of a large field will discover at once whether there is any stoppage of the water; and by means of a spade or shovel it will be remedied with little trouble. When the surface binds, as it does in some soils, and prevents the access of air to the roots, the land is harrowed or hoed, and in a few days the effect will be apparent.

It is a very common notion that good wheat and bean land is not well adapted to the growth of roots, especially of such as are usually fed off the land by sheep, because the treading of animals is injurious in winter and spring, when these crops are usually wanted; and if they are carted off, the wheels and the horses make such impressions as are equally detrimental or more so. But all roots, even the white turnip, will grow luxuriantly on heavy soils well prepared and manured; and they may be so managed as to be taken off before the winter. The land being ploughed immediately on the removal of the roots, will be well prepared for wheat, or, when mellowed by the winter's frost, may be sown in spring with beans, barley, or oats. The manure will be incorporated with the soil, even if it has been put on in a very fresh state for the roots, which can only be recommended on very compact soils. If the root crops are well cleaned, fallows may be avoided, or at least recur very seldom, and then only when root weeds have accumulated from neglect.

When the wheat has blossomed, and the grain in the ear is fully formed, it should be watched, and as soon as the seed feels of the consistence of tough dough, and the straw is dry and yellow below the ear, it should be reaped. The skin of the grain will be thinner, and its substance will harden readily by mere drying, while the straw is better fodder for the cattle. It is found by experience that the increase of flour by adopting this method is very considerable. The operation of reaping is now best done by the reaping machine.

The choosing of wheat for seed is a matter of great importance. Some farmers like to change their seed often; others sow the produce of their own land continually, and both seem persuaded that their method is the best. The fact is, that it is not always the finest wheat which makes the best seed; but it depends on the nature of the land on which it grew. Some soils are renowned far and wide for producing good seed, and it is well known that this seed degenerates in other soils, so that the original soil is resorted to for fresh seed.

While the wheat is growing it is exposed to various accidents, which it is often difficult to foresee, and more difficult to guard against. The smut and burnt-ear are diseases which may be generally prevented by a proper preparation of the seed before it is sown. Many corrosive substances have been recommended to steep the seed in, such as blue vitriol, one pound to a quarter of a grain, dissolved in water enough to wet every seed. It seems, however, that washing the seed well with plain water, or with salt and water, and afterwards drying it with quicklime, sufficiently destroys the germ of the smut to prevent its propagation. The most common steep is water in which so much salt has been dissolved as will enable it to float an egg. In this the seed may be left for twelve hours or more, and then spread on a floor and mixed with as much quicklime as will absorb the moisture, and allow it to be sown or drilled, without the grains adhering to one another.

In the second volume of the 'Journal of the Royal Society of Agriculture of England,' Part I., is a valuable paper, by the Rev. T. S. Henslow, on the diseases of wheat. He describes the different *fungi* which produce the various diseases of pepper-brand, dust-brand, rust, and mildew. The ergot in wheat is an excrescence from the ear, like a small horn, into which the seed is transformed. It has a poisonous quality and a medicinal one. The cause of this monstrosity in the seed is not fully known. It is supposed to be caused by the puncture of some insect, introducing a virus which has entirely altered the functions of the germ, and made it produce this ergot, instead of a healthy seed. Another disease of the seed is called ear-cockles, and is caused by extremely minute insects like eels, which fill the skin of the seeds, instead of flour. This insect, which is called *Vibrio tritici*, is described by Mr. Bauer in the 'Philosophical Transactions' for 1823. This disease is not so common as the smut and the pepper-brand. It is probable, according to Mr. Henslow, that the animalcula may be killed by exposing the grain to a certain heat, so as not to destroy its power of vegetation, but sufficient to kill the vibrio. The wheat-midge (*Cecidomyia tritici*) is another external enemy, which does more harm to the crop than is generally known. It deposits its eggs at the root of the germ in the ear, and prevents the filling of the grain, the maggot living on the nutritive juices which should produce the farina. The Hessian fly, which caused such depredations in America and Canada at one time, is a different species of the same fly. This deposits its eggs in the straw near the root, and thus destroys the whole plant. We must refer the reader for further particulars to the paper above mentioned.

Great attention has been lately paid to the introduction of the best and most prolific varieties of wheat, and by merely observing what ears appear much superior to others in a field of ripe wheat, and collecting these to be sown separately in a garden or portion of a field, the variety, which may have been produced by some fortuitous impregnation, or some peculiarity in the spot where it grew, is perpetuated. By carefully selecting the seed which is best adapted to the soil, by a more careful and garden-like cultivation, and by adding those manures which are found most adapted to favour its perfect vegetation, crops of wheat have been raised, which, at one time, would have been thought marvellous; and the average produce of this important grain has been increased on all soils.

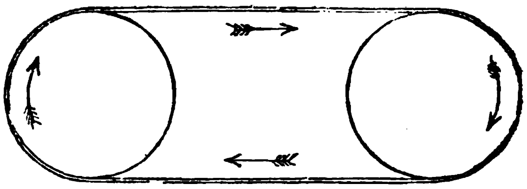
WHEEL. A mechanical contrivance, by means of which the intermittent and limited action of the lever is extended to any distance, and made to act continuously and uniformly. The direction and the velocity of movement of a machine are commonly regulated by the disposition and character of the wheelwork which enters into its composition; but the principle upon which all wheels really act, consists in the application, in a continuous manner, and in a circular direction, of the power obtained by leverage.

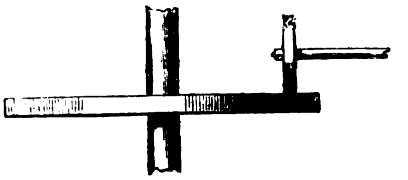
Wheels are either of the kind known as *carriage* wheels, or *friction* wheels, or *teethed* wheels; including under the second division *band* wheels, and under the third the various kinds of *cog, trundle, spur, crown*, and *bevilled* wheels. In a system of wheelwork the wheels may be either *multiplying* or *diminishing*, according to their relative sizes; they may either perform complete revolutions, or, as in the case of *balance* wheels, only revolve over small arcs; they may revolve either horizontally or vertically; they may be used to produce motion or to communicate it; or, finally, they may be used for the purpose of regulating the velocity of the machinery to which they are annexed, as in the case of *fly* wheels. Water-wheels constitute a separate class of machinery, known under the same generic name of wheels, in which the power is produced by the direct action upon the wheel itself. [WATER-WHEELS.] In ordinary wheels the power is applied originally to the shaft bearing them, by the intervention of cranks, handles, winches, or levers.

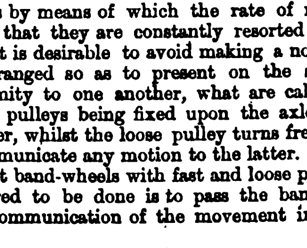
In carriage wheels the object sought to be attained is to convert a sliding friction into a rolling one, in order to facilitate the horizontal movement of heavy loads. The efficiency of a carriage wheel, therefore, consists in the length of the lever it offers (or, in other words, upon its diameter); upon the direction in which the power is applied to it; and upon the small extent of surface producing friction; always provided that the surface should be sufficient to prevent the load from forcing the wheels into the materials over which they run. It is for the avowed object of insuring the application of the power exercised by a horse, in drawing a cart or carriage, *above* the horizontal line passing through the centre of the fore wheels, that they are made smaller than the hind wheels; but, as an abstract proposition, it may be stated that the larger a wheel is, the greater is the useful effect it produces, provided the line of draught pass horizontally through its centre. Another abstract proposition with respect to carriage wheels is, that the narrower their surfaces, the less friction they must develope; but evidently the character of the roadway over which the load travels must re-act upon this condition, for upon a soft surface a narrow wheel, heavily laden, would compress the road materials, and thus create a continually occurring series of obstacles to its own progress. Upon soft roadways, under heavy loads, carriage wheels must therefore be made wide upon the face of the felloes; for quick traffic, on hard roads, when the carriages do not convey heavy loads, narrow wheels are generally resorted to.

In the earliest wheeled carriages, the wheels were made of solid planks, and the axles were fastened to them, so that wheel and axle turned together; the load in such cases being borne upon collars worked upon the axles. Rude carts of this description have been used in England within a very short period, and they may still be seen upon the provincial roads of such countries as Spain or southern Italy. When the roads are habitually of a superior character, however, carriage wheels are made as lightly as the work they are required to perform will admit of; and they consist usually of a *nave*, or centre boss, into which the *spokes* or radiating arms are fastened at one end, whilst the spokes at their other ends bear the *felloes*; the whole assemblage being bound together by an iron *tire*, nailed to the felloes whilst it is hot, in order that the shrinkage of the iron in cooling may "force the various joints home," as workmen say. The nave is usually bored out to receive a *box* of iron (or of gun metal in some cases), in which the collar of the axle is inserted, so that the wheels on the respective sides of the carriage can revolve independently of one another in their horizontal positions, but are maintained at fixed distances apart horizontally. In wheeled carriages the bodies are attached to the axles, either with, or without, the intervention of springs; in four-wheeled carriages the front pair of wheels is usually made to revolve on a pivot fixed under the fore part of the body. Of course the dimensions of all the details of carriage wheels must depend upon the weights they are intended to transport, and upon the velocity at which they are intended to travel; in railway carriages the naves, spokes, felloes, and tires of the wheels are executed of iron, or of steel; in common carriages, wood is the material principally used.

The friction wheels of mill-work are introduced for the same purpose that wheels are adapted to ordinary carriages; that is to say, for the purpose of converting sliding friction into rolling friction. They are used to facilitate the horizontal or vertical movement of traversing beds, of guide rods, &c., and therefore the only conditions they are required to fulfil are, that they should revolve freely on their own axles, and present smooth surfaces (able to retain a lubricating fluid) to the bodies moving over them, or over which they may move. Driving band-wheels, on the contrary, are fixed on their bearing shafts, and have their surfaces formed in such a manner as to cause the straps, or bands, to adhere to them by their mere friction upon the asperities, and thus to produce motion in the secondary band-wheels of the machinery to which they are applied, by the rotation of the first wheels. In some cases also, motion is communicated by means of wheels whose surfaces are in contact, and which act upon one another by the mere unevenness of those surfaces; if, however, any serious resistance should be encountered, the wheels would be likely to slide over one another, and they are therefore only used in light and delicate machinery. Indeed all descriptions of band-wheels are exposed to the same objection, because they only communicate motion by the friction of the bands upon the respective surfaces, and when the resistance exceeds that friction, the bands must slide over the wheels; but they present so many facilities for the introduction of *speed* pulleys, (that is to say, of pulleys by means of which the rate of revolution may be modified at will) that they are constantly resorted to in machinery, especially when it is desirable to avoid making a noise. Band-wheels are commonly arranged so as to present on the same axle, and in immediate proximity to one another, what are called *fast* and *loose* pulleys; the fast pulleys being fixed upon the axle, so that the two must turn together, whilst the loose pulley turns freely upon the axle, and does not communicate any motion to the latter. When, therefore, it is desired to put band-wheels with fast and loose pulleys out of gear, all that is required to be done is to pass the band upon the loose pulley, and the communication of the movement immediately ceases.

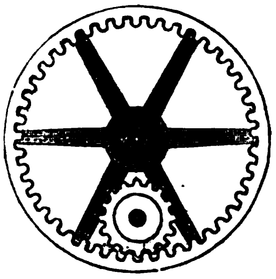


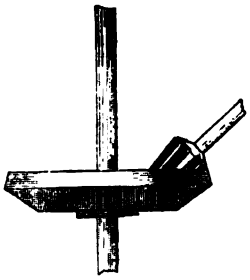




Band-wheels also present great advantages from the ease with which they admit of the change in the direction of the motion. If, for instance, it be desired to reverse the motion, the band is simply crossed, and endless bands may be made to communicate motion in every possible direction with respect to the driving pulley. Long bands are, however, objectionable, as they have a tendency to stretch; and it must also be observed that the circumferences of band-wheels should be made slightly rounded, because there is a tendency in bands running over pulleys to work towards the portions of those pulleys which are of the largest diameter; and thus, perhaps, to "cast off." The friction cones, used by rope-spinners, may be cited as amongst the most valuable illustrations of the use of these modifications of wheel-work; as may also be cited the speed pulleys of lathes, the carrying-bands of printing machinery, the friction-rollers upon which the endless sieves of paper-making machines traverse, &c.

In *teethed* wheels, a series of projections, or *teeth*, are formed on the outer rim of one wheel, which work into corresponding projections upon the outer rim of the wheel connected with it, in such a manner as to allow the teeth of the former to communicate their motion by the sliding or rubbing of their surfaces upon the surfaces of the teeth of the second wheel. *Cog*-wheels are those in which the teeth are made of a different material to the wheel itself, but the cogs are nevertheless of the same outline in principle as ordinary teeth. *Trundle*-wheels are those in which the teeth are formed by cylinders of small diameter, and short lengths, fixed between two discs; they are much used in coarse mill-work, on account of the smoothness of their action, and the small friction to which they give rise. *Pin*-wheels are those in which similar cylinders are placed upon the surface of a revolving disc; *crown*-wheels are those in which the teeth are cut out of the rim of the wheel; *annular*-wheels are those in which the teeth are cut upon the inner surface of the rim; *bevilled*-wheels are those in which the faces of the teeth are portions of cones whose apices meet, and are inclined so as to allow the motion of the first, or *driving*-wheel to be changed in its direction; *spur*-wheels are those which transmit motion in directions parallel to that of the revolution of the driving-wheel. The first wheel in all these instances bears the name of the *first motion* or *driving*-wheel; the secondary wheel is called the *follower*, or the *pinion* in the case of cog-wheels, but sometimes it is called the *wallower*, in the case of trundle-wheels. The wheels themselves are composed of the central boss, the arms, and the rim, bearing the teeth; sometimes, however, in small pinions the arms are replaced by a solid plate, and then they are known by the name of *plate*-wheels; the inner rim of a first motion annular-wheel is known by the name of the *annulus*. When it is essential that no sliding should take place on the surfaces of wheels the faces are broken into what are called *compound* or *combined* wheels, which consist of a series of parallel concentric ranges of teeth, so placed that the contact of any pair of teeth should only be momentary. Dr. Hooke introduced this kind of wheel, and indeed it is at times known by his name; but it is too complicated, and too liable to fracture, for ordinary work.





In setting out a wheel, the basis of the operation is the *pitch circle*, or the working circumference; the term *pitch* itself means the distance apart of the centres of the teeth upon that circle. The only condition which regulates the pitch is, that the material should be strong enough to bear the effort to which it is to be exposed; and in practice it is found that cast-iron wheels work satisfactorily with pitches varying between 1 and 3 inches in large wheels, and between a quarter of an inch and three quarters of an inch in very small ones. The number of teeth depends upon the circumference, and upon the pitch; or calling the number of teeth n, the circumference c, and the pitch p; then $n=\frac{c}{p}$, all the dimensions being in inches; or the diameter d will be found by making $d=\frac{p\,n}{3{\cdot}1416}$. The velocities at which the various wheels of a piece of machinery are required to revolve determines their respective diameters, and they are calculated upon the principles to be described in the sequel; but it is to be observed that the *true* radii are always rather larger than the *primitive* radii, which latter serve to define the pitch circle; the true radii, on the contrary, define the extremities of the teeth. Another general law is that the number of teeth in the *spur*- (or driving-) wheel is to the number of teeth in the *pinion* (or follower) in the ratio of their respective radii; or calling the diameter of the spur-wheel A B; the diameter of the pinion C D; and the number of teeth on the former N; then the number of teeth on the pinion will be found thus:—$AB : CD :: N : n$. The outlines of the teeth are ascertained by dividing the pitch circle into equal parts corresponding with the proposed number of teeth; the pitch is then subdivided into four parts, to obtain the centres of the intervals, and also the flanks of the teeth within the line of the pitch circle. Beyond that line the flanks of the spur teeth are formed by portions of an epicycloid generated by the revolution of a circle, whose diameter is equal to the radius of the pinion pitch circle around the pitch circle of the spur; and the flanks of the extremity of the teeth of the pinion are formed by portions of a hypocycloid generated by the revolution of the circle before named on the interior of the pitch circle of the pinion itself. The projection of the teeth beyond their respective pitch circles is regulated by the condition that the epicycloidal and hypocycloidal curves shall be sufficiently long to cause the latter to bear upon the side of the teeth, through an extent of circumferential movement equal to the length of the pitch. Practically this length may be found by describing a circle of a diameter equal to the radius of the pinion upon the line of centres, and at the point where it intersects the radial line forming the flank of the second tooth, describing the true radius of the spur. The depth of the intervals is made so as to leave a small space between the extremity of the teeth and the rim, and it is customary to leave a little play between the teeth, equal to about $\frac{1}{15}$th or $\frac{1}{20}$th of the pitch; the interior angles of the teeth are rounded off in order to increase their strength. In setting out a pinion intended to drive a lantern-wheel, the teeth must still be made portions of epicycloids; but in the case of racks driven by teethed pinions the curves must be involutes of the pitch circle, and in annular wheels the teeth of the annulus must be portions of a hypocycloid. The portion of the tooth beyond the pitch circle, to which the above peculiar forms are given, is occasionally known by the name of the *addendum*, and it is usually about $\frac{3}{10}$ths of the pitch employed. In common construction the proportions of the various parts of a pair of teethed wheels gearing into one another are as follows:—

Depth of addendum	$\frac{3}{10}$	of pitch.
Working depth, from addendum to flank . .	$\frac{6}{10}$	"
Whole depth	$\frac{7}{10}$	"
Thickness of tooth on pitch line	$\frac{5}{11}$	"
Breadth of space on ditto	$\frac{6}{11}$	"

In small wheels with few teeth the depth of the addendum must be increased above the proportion above-mentioned.

Bevilled gearing consists of frustra of cones, which are supposed to roll upon one another, and whose apices are supposed to meet in one point; and in this case the form of the addenda ought to be a portion of a spherical epicycloid, according to strict theory, but in practice a much more simple form, devised by Telford, and described in Buchanan's 'Treatise on Mill-work,' p. 58 (1841), is used. Indeed, it is very rarely that the faces of wheels are made with cycloidal forms of any description; and practical men adopt, instead of them, simpler circular forms. Professor Willis, in his 'Principles of Mechanism,' has described an instrument of his own invention, for drawing the teeth of wheels by arcs of circles; and has accompanied the description by tables illustrating its use. The reader is referred to the various books above mentioned, and to Warr's 'Construction of Machinery,' Camus 'On the Teeth of Wheels,' Hachette's 'Traité des Machines,' Armengaud's 'Dessin Industriel,' and W. Johnston's 'Practical Mechanic,' for more specific details with respect to the principles upon which teethed wheels of the various kinds enumerated are designed. Professor Willis's 'Principles of Mechanism' may, perhaps, be cited as containing the most valuable information on the subject.

It is necessary here to add that in some cases it is desirable to produce in machinery an intermittence in its action, or a certain alternation of motion and of rest, in the wheels gearing into one another. This is effected by leaving a portion of the circumference of the driving-wheel without teeth for a length corresponding with the desired period of repose; precautions, however, must be taken to insure that the teeth should fall into their proper places when contact is restored, for which purpose pins and guides on the face of the wheel are commonly introduced. *Ratchet*-wheels, or those which only revolve in one direction, and have a species of alternate reciprocating action on the driver (in this sense, that they are raised gradually for a certain portion of the revolution, and are then suddenly released), are introduced for the purposes either of preventing the wheel-work from revolving in more than in the direction originally selected, or for obtaining alternate vertical or horizontal motion in the shafts of a piece of machinery. The pin which prevents the alteration of the rotation of a ratchet-wheel, is usually placed on a pivot, and is able to be thrown out of gear at will: it is commonly known by the name of a *paull*. Mill work of all kinds may either be kept permanently in gear, or it may be constructed so as to allow any of its parts to work, or to rest, independently of the general combination, by means of couplings, clutch-boxes, friction, or reversing-gear. In the construction of machinery, wheels play very important parts by the action of drivers upon the various combinations for producing change of motion, such as racks, endless screws, cams, eccentrics, teethed arcs, &c.; but the consideration of these functions of wheels, as also of those by which they are made to regulate the motion of the machinery to which they are attached, by reason of their power of retaining momentum, belongs especially to the province of applied mechanics. Before closing this article, however, it is essential to allude cursorily to some of the mechanical conditions involved in the application of wheels.

The simplest manner in which those contrivances for the transmission of power are used, is the one known by the term of the wheel and axle. [WHEEL-AND-AXLE.] In the *windlass* the power is applied to the axle by means of a cranked lever revolving in a circular path, instead of by a wheel; but the principle of the action of this form of lever is precisely the same as that of the wheel, with only the difference that the moments of inertia of the moving machinery are slightly changed. [WINDLASS.] In *tread-wheels* the power is obtained by causing the men or animals who act upon the machinery to exercise their effect, by the application of their weight, upon the periphery of the wheel. When equable motion is required to be produced by a wheel animated by a variable power, it is obtained by the interposition of a cone, or of some such contrivance for increasing the leverage of the power in proportion as the power itself diminishes; as, for instance, in the spiral springs and fusees of watch-work.

The power of a combination of two cog-wheels is ascertained by multiplying the distance at which the power is applied from the centre of the first wheel, by the radius of the second wheel; and dividing that sum by the sum of the distance at which the resistance acts from the centre of the second wheel, multiplied by the radius of the first: the quotient will represent the ratio of the power to the resistance it is able to overcome. In a combination of any number of teethed wheels the power of the system may be ascertained by taking the radii of the wheels as the even terms of a series, and the distances at which the power and resistance act from the centres of their respective wheels as the odd terms (or the intermediate ones) of the series; then the product of the odd terms, divided by the product of the even terms, will represent the ratio of the power to the resistance. The even terms will in this case represent the flyers or *drivers*, and the odd ones the *followers*, and the product of the former will give the velocity of the power, whilst that of the latter will give the velocity of the weight or resistance.

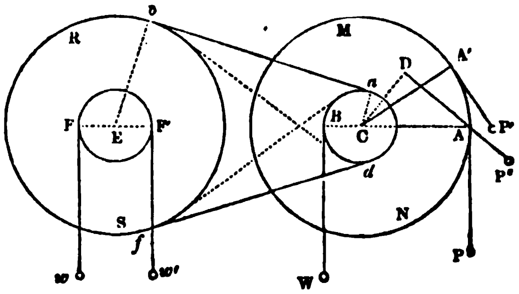
Very good practical rules, and examples for their application, of the relations of the various parts of a system of wheel-work are to be found in the Memorandum-book of Mr. Telford, inserted in his 'Biography,' and reprinted in the 'Engineer's Pocket Book;' but none of these easy practical solutions of the mechanical problems involved in this branch of applied mechanics, can dispense the engineer from the study of their principles. These are discussed at considerable length in such works as those previously mentioned, and in Moseley's 'Mechanics applied to the Arts;' his work on 'Engineering and Architecture;' in Warr's 'Dynamics;' Weisbach's 'Mechanics of Machinery;' Borgnis, 'Traité complet de Mécanique appliquée aux Arts;' Dupin's 'Géometrie et Mécanique des Arts;' Lanz et Bétancourt, 'Essai sur la Composition des Machines,' &c.; and to them the student is earnestly referred.

WHEEL-AND-AXLE, is a machine consisting usually of a cylinder to which a wheel is firmly united, so that the mathematical axes of both are coincident. The wheel and cylinder are of wood or metal, and the diameter of the former is greater than that of the latter.

A cylinder on the circumference of which are fixed exteriorly boards whose planes, if produced, would pass through the axis, and which (being turned by the force of running water, or by the weight of men in the act of stepping from one board to the next above it) is employed to raise a heavy body by means of a rope passing over a smaller cylinder on the same axis, as in the treadmill, is a simple machine of this kind: the same may be said of a hollow cylinder which, with its axle, is made to revolve by men or animals walking in the direction of its circumference, in its interior surface. The capstan, the windlass, and the helm-wheel of a ship are only so many different forms of the same class of machines. Frequently also the axle is made to carry a wheel with teeth on its circumference, in order that, by revolving, motion may be communicated to machinery: such are the wind and water mills which are employed for grinding corn.

When it is required to exhibit the mechanical properties of the wheel-and-axle, a weight representing the moving power is applied at one extremity of a string which at the other extremity is attached to and passes round the circumference of the wheel; and a weight, representing the resistance to be overcome, is applied in like manner at one end of a string which passes round the axle or cylinder. Let MN (in *fig.* 1) be a section passing through the wheel and cylinder perpendicularly to their common axis, and let CA, or CA′, and CB be the semi-diameters of the circles in that section: let P represent the moving power and W a weight to be raised, or held in equilibrio; AP or A′P′, and BW, being the directions of the strings to which those weights are attached; and for simplicity, let these lines be in one plane and coincident with tangents to the circles at A, or A′, and at B. Here it is evident that the mechanical power of the wheel-and-axle is the same as that of a lever of the first kind; for (the thickness of the ropes and the weight and inertia of the materials being disregarded) the forces P and W acting perpendicularly to the arms CA and CB, the effect is the same as if those forces were applied immediately at the extremities of the straight line AB, or of the bent line A′CB, and C being the fulcrum or point of support, we have, by the nature of the lever, in the case of equilibrium,

Fig. 1.



$$\mathrm{P} : \mathrm{W} :: \mathrm{BC} : \mathrm{AC}\ (=\mathrm{A'C}),\ \text{or}\ \mathrm{P} = \mathrm{W} \cdot \frac{\mathrm{BC}}{\mathrm{AC}}.$$

The wheel-and-axle has manifestly however a great advantage over the simple lever, since the weight W may be raised to any height which is consistent with the lengths of the ropes, by winding the rope round the axle.

If the power P or P′ do not act in the direction of a tangent to the circle, but in some other, as AP″; then letting fall CD perpendicularly on P″A, produced if necessary, we have, by the lever,

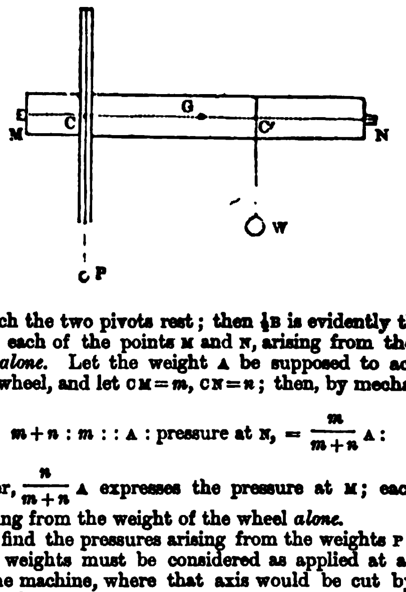
$$\mathrm{P''} : \mathrm{W} :: \mathrm{BC} : \mathrm{CD}.$$

If the ropes to which the weights are attached have sensible thicknesses, and it is thought proper to take those thicknesses into consideration, the ropes may be conceived to be reduced to their mathematical axes, and these to pass over the circumferences of the wheel and cylinder at distances equal to the semidiameters: thus, if r and R be the semidiameters of the ropes passing over those circumferences, respectively, we obtain, in the case first supposed,

$$\mathrm{P} : \mathrm{W} :: \mathrm{BC} + \mathrm{R} : \mathrm{AC} + r.$$

If it be required to determine the pressures on the supports of a wheel-and-axle when the weights applied to it are in equilibrio, and the whole machine is at rest, the investigation may be conducted in the following manner:—Let the weight of the wheel be represented by A and that of the cylinder by B; also let M and N (in *fig.* 2) be the points on which the two pivots rest; then ½B is evidently the pressure supported on each of the points M and N, arising from the weight of the cylinder *alone*. Let the weight A be supposed to act at C, the centre of the wheel, and let CM $= m$, CN $= n$; then, by mechanics,

Fig. 2.



$$m + n : m :: \mathrm{A} : \text{pressure at N}, = \frac{m}{m+n}\mathrm{A}:$$

in like manner, $\frac{n}{m+n}\mathrm{A}$ expresses the pressure at M; each of these pressures arising from the weight of the wheel *alone*.

In order to find the pressures arising from the weights P and W, the sum of those weights must be considered as applied at a point G in the axis of the machine, where that axis would be cut by a vertical plane passing through the common centre of gravity of the two weights: let C and C′ be points in which the axis is cut by vertical planes passing through the respective centres of gravity of P and W; then, in order to find G, we have, by mechanics,

$$\mathrm{P} + \mathrm{W} : \mathrm{CC'} :: \mathrm{P} : \mathrm{CG}\left(= \frac{\mathrm{P}.\mathrm{CC'}}{\mathrm{P}+\mathrm{W}}\right);$$

$$\text{hence}\ \frac{\mathrm{P}.\mathrm{CC'}}{\mathrm{P}+\mathrm{W}} + m,\ \text{or}\ \frac{\mathrm{P}.\mathrm{CC'} + m(\mathrm{P}+\mathrm{W})}{\mathrm{P}+\mathrm{W}},\ = \mathrm{MG},$$

$$\text{and}\ n - \frac{\mathrm{P}.\mathrm{CC'}}{\mathrm{P}+\mathrm{W}},\ \text{or}\ \frac{n(\mathrm{P}+\mathrm{W}) - \mathrm{P}.\mathrm{CC'}}{\mathrm{P}+\mathrm{W}},\ = \mathrm{GN}:$$

therefore, again by mechanics,

$$m+n : \frac{\mathrm{P}.\mathrm{CC}'+m(\mathrm{P}+\mathrm{W})}{\mathrm{P}+\mathrm{W}} :: \mathrm{P}+\mathrm{W} : \text{pressure on}$$

$$\mathrm{N}\left(=\frac{\mathrm{P}.\mathrm{CC}'+m(\mathrm{P}+\mathrm{W})}{m+n}\right),$$

and, in like manner, $\frac{n(\mathrm{P}+\mathrm{W})-\mathrm{P}.\mathrm{CO}'}{m+n}$ expresses the pressure on M.

Consequently the whole pressure on M is

$$\tfrac{1}{2}\mathrm{B}+\frac{n\mathrm{A}+n(\mathrm{P}+\mathrm{W})-\mathrm{P}.\mathrm{CC}'}{m+n},$$

and on N, is $\tfrac{1}{2}\mathrm{B}+\frac{m\mathrm{A}+m(\mathrm{P}+\mathrm{W})+\mathrm{P}.\mathrm{CO}'}{m+n}$.

If the wheel and cylinder are in a state of motion about their mathematical axis, the pressure on the supports will evidently be diminished by the force with which the common centre of gravity of the weights P and W tends to descend; the value of this force is investigated in treatises on dynamics.

If two wheels and cylinders are connected together by a string *b a d f* (in *fig.* 1), or by teeth in the circumferences, as in most forms of rack-work, the ratio between the power P and the resistance *w*, in the case of equilibrium, may be determined by the same rule as would be employed if those weights were at the opposite extremities of a double lever of the first or second kind. For the power P may be conceived to be applied at A perpendicularly to the semidiameter CA, and it will be in equilibrio with a resistance at *a*, perpendicular to C*a*, which may be expressed by $\mathrm{P}.\frac{\mathrm{CA}}{\mathrm{C}a}$: let this be represented by *p*. Now this force at *a* may, in consequence of the string passing round the axle CB and the circumference of the wheel RS, be conceived to be a moving power applied at *b* perpendicularly to E*b*; and this will be in equilibrio with a resistance *w* at F, acting perpendicularly to FE, which may be expressed by $p\,\frac{\mathrm{E}b}{\mathrm{EF}}$; therefore, substituting in it the above value of *p*, we have $w=\mathrm{P}.\frac{\mathrm{CA}}{\mathrm{C}a}.\frac{\mathrm{E}b}{\mathrm{EF}}$. And in like manner may the relation between the power and resistance be found, in the case of equilibrium, whatever be the number of wheels and axles.

It is to be understood, in the above description, that the axles of the two wheels MN and RS are supposed to be parallel to one another and to the horizon; and that the parts of the string *b a d f* are in a vertical plane perpendicular to those axes, in order to avoid the reductions which would be necessary on account of a loss of power resulting from an oblique action of the forces at *a* and *b*. The forces acting in AP and BW, or F*w*, are also supposed to be exactly or very nearly in one vertical plane, in order to avoid the strain on the axle which would otherwise take place. [MATERIALS, STRENGTH OF.]

If the string passing over the circumference of the wheel RS and the axle CB were to cross itself, as represented by the lines *b d a f*, the relation between the powers would be the same as before, but the weight *w'* would be raised in the direction *w'*F' instead of *w*F.

It is easy to perceive that (as in the lever and other mechanical powers) the spaces described by the weights B and W, in a given time, when in motion, are to one another in the inverse ratio of those weights; for the spaces described are respectively equal to the lengths of the strings which pass over the circumferences of the wheel-and-axle in the given time; and these lengths are proportional to the circumferences, or radii, that is, inversely as the weights acting at the circumferences.

Hence the advantage in the wheel-and-axle may be increased either by increasing the radius of the wheel, or by diminishing that of the axle. In the latter case, of course, the axle would soon become too weak to sustain the weight. This is beautifully avoided by the use of a *compound* axle, one part of which is of smaller radius than the other. One end of the cord carrying W is wound round the *thicker*, and the other, in a contrary direction, round the *thinner* part. As P descends, some of the cord unwinds from the thinner axle, while another part is wound up round the thicker; but as the latter part, of course, exceeds the former in length, the weight is raised in this proportion. Thus we may have an axle of virtually vanishing radius, and may, consequently, almost indefinitely increase the power, but, of course, only at the expense of time.

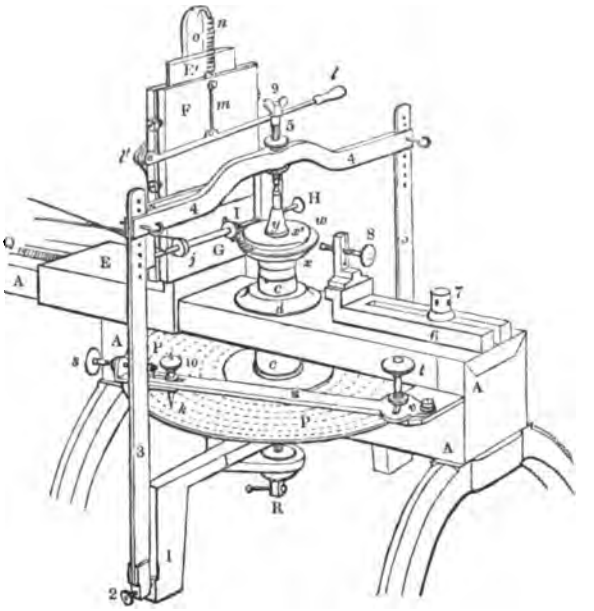
Taking the measurements as in *fig.* 1, and representing the radius of the *thicker* axle by BC, and that of the *thinner* by a quantity *a*, less than BC; since the whole weight W is supported by the *two* parts of the cord, the tension of the cord $=\tfrac{1}{2}\mathrm{W}$.

Hence, by mechanics, taking moments about C, we get,

$$\mathrm{P}.\mathrm{CA}+\tfrac{1}{2}\mathrm{W}a=\tfrac{1}{2}\mathrm{W}.\mathrm{CB}$$
$$\therefore \mathrm{P}.\mathrm{CA}=\tfrac{1}{2}\mathrm{W}(\mathrm{CB}-a)$$
$$\therefore \mathrm{P}:\mathrm{W}::\tfrac{1}{2}(\mathrm{CB}-a):\mathrm{CA}.$$

WHEEL-CUTTING, a term applied to a particular branch of practical mechanics, which comprehends the modes of cutting the teeth in the wheels used by watch and clock makers and for other mechanical purposes. The engines used for this purpose vary in their construction according to the wants or caprice of the artists who use them. We shall content ourselves with giving a description of the engine commonly employed, with a few remarks on the kind of tools used for cutting the spaces between the teeth, which operation is usually termed cutting the teeth of a wheel, although in reality the teeth are those portions of the metal which are left standing. We shall, however, employ the common phrase, as it will perhaps be best understood by all who feel an interest in the art.

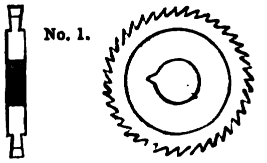
Description of the engine commonly used:—AAAA a strong frame of cast-iron consisting of two parallel plates, the stouter the better firmly connected together, but so that the plates are from 3 to 5 inches apart, to allow the dividing-plate PP to revolve between them. The plate PP is fixed firmly to the axis *c* (about 8 or 9 inches long), which works at its upper end in a collar *d*, in the upper plate, and its lower end in the centre of a screw, R: this axis *c* has a hole down from its upper end, about three-fourths of its length, to receive the smaller axes, arbors, or pinions of the wheels which are to be cut. E is a horizontal slide, of which the vertical part E' is formed into a dove-tail, on which slides the vertical slide F, to which is securely attached a frame G, having two projecting sides through which pass two screws, one of which is seen at H. These screws have female centres to receive the ends of the arbor which carries the cutter I: *j*, a pulley on the cutter-arbor which receives the band by which motion is communicated to the cutter I; *l*, the handle of a lever, whose centre of motion is at *l'* on a piece projecting from the back of the fixed dovetail E', to which is attached the connecting-rod *m*, for depressing the slide F, and thereby passing the cutter through the wheel; *o*, a piece attached to the back of the dovetail E', for the purpose of fixing the spring *n*, one end of which is attached to the slide F, and operates to bring up the slide after the cutter has passed through the wheel. The slide E is for the purpose of bringing the cutter to the requisite distance from the centre of the wheel to be cut, and has a screw, not seen in the drawing, for the purpose of setting it fast when brought by the screw Q to its proper place. The dividing-plate PP has on its surface a number of concentric circles, which occupy that portion of the plate nearest its circumference: these circles are each accurately divided into such a number of equal parts as are likely to be suitable for the wheels required to be cut; the outer circles, being the largest, generally contain high numbers, such as 400, 360, 192, 168, 160, 150, 140, 136, 130, &c., and with these almost any common number of teeth can be cut. Firmly fixed on a moveable centre or joint attached to the frame of the engine is an index *u*, capable of a motion on its joint parallel to the plate PP, and having at its end a pin *k*, with a rather long conical point. On the plate PP, at the intersection of each division with its corresponding circle, is drilled a hole; and if these holes are drilled quite through the plate all the better. The pin *k* is attached to the index *u* by a moveable piece which is acted upon by the screw *s*, and serves the purpose of shifting the plate PP any small quantity less than the distance of a single division on the plate; and 10 is a nut to set the pin *k* fast in any required position.

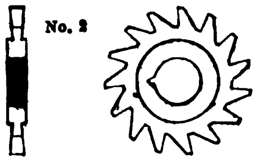


The index, being placed with its conical point *k* in one of the holes in any circle by means of slit *v* (say that of 360 divisions), is screwed fast by the screw *t*, and the elasticity of the index keeps it sufficiently tight in the hole to prevent the plate and arbor from moving round: if the end of the spring or index be now lifted up by the hand, and the plate be moved round till the next division or hole in the same circle comes under the conical point, and the point *k* be then dropped into it, the distance moved over by the plate, and also by the wheel which is screwed or otherwise fixed on to the end of the arbor *c*, will be $\frac{1}{360}$th part of a circle. The cutter having been adjusted to such a distance from the centre of the arbor *c* as is required to cut a proper depth into the wheel, the operation of cutting is performed by bringing down the slide F which carries the cutter-arbor by the lever *l*, the arbor being carried round by the band which passes round the pulley *j*, and a wheel similar to a lathe-wheel, which the operator keeps in motion by the foot acting on a treadle in the same way as in a common lathe. As soon as the cutter has passed through the thickness of the wheel, the pressure is taken off the lever by which the cutting-frame or slide has been depressed, and it is brought back to the position it had before by the spring *n*, the plate is shifted one division, and the operation of cutting is repeated. It will be perceived that any number can be cut from each circle, provided the required number is an aliquot part of the divisions in the circle used: thus, on the circle of 360, by passing over two divisions between each cutting, 180 will be cut; three divisions, 120; four divisions, 90; and so on.

In some engines the edge of the dividing-plate, or rather a rim just within the edge on the under side of the plate, has a screw cut upon it, into which a tangent-screw is made to act; and the head of this screw consists of a small wheel, or dividing-plate, removeable at pleasure, in order to substitute another of a different number. By such an arrangement as this just described, not only may any number (even prime numbers) be cut, but the plate itself may be divided. The cutting of wheels, or rather shifting the plate by the screw, would take too much time for ordinary wheel-cutting; hence the numbers most in use are drilled in the plate as above described. A great many ingenious methods are resorted to in wheel-cutting for the purpose of cutting odd numbers, for moving the plate over any number of divisions rapidly without the possibility of making a mistake, the details of which our limits will not allow us to go into: what we have said above we deem sufficient to illustrate the principle. It is necessary here to observe that the cutter, previous to commencing to operate, should be adjusted so that a plane passing through the centre of its cutting-edge, and parallel with its sides, should pass also through the centre of the arbor on which the wheel is fixed; otherwise the teeth will not be cut in straight to the centre, and will have the appearance of being bent on one side. It is also necessary that the downward motion of the slide containing the cutter-arbor should be perfectly at right angles with the plane of the wheel. We have hitherto spoken of the wheels as being screwed to the arbor *c*, but we have also said the arbor *c* is hollow, for the purpose of receiving the axes of the wheels to be cut. This hollow arbor is, in fact, capable of receiving end-pieces, which are firmly fixed therein; and it is on these latter pieces that the wheels which have no axes of their own, but simply a hole through them, are screwed. But when the wheel to be cut is already fixed on an axis, the hollow arbor is used with an apparatus shown in the figure, which we shall now describe:—1, 1, part of a very firm bar attached to the lower frame, and extending horizontally across the centre of the engine-plate, the extremities of which bar terminate in two pins or pivots; 2, 2, one of which is not seen, extending a short distance beyond the edge of the dividing-plate; on to these pins are hooked two pieces, 3, 3, which, at their upper ends, pass through slits in the piece of iron, 4, 4, which has a screw, 5, passing through its centre. (In all this apparatus, except the screw, 5, there must be no nice fitting, but perfect freedom.) The screw 5 has a centre, either male or female, by which it presses down the hollow cone *y*; but the foregoing apparatus, called the gallows, will be best understood by describing the mode of putting on a wheel having an arbor in it:—Remove the gallows; on to the end of axis *c* drop a flange *x*, a little less in diameter than the circle which corresponds with the bottom of the teeth to be cut: through the centre of this flange drop the longer part of the arbor of the wheel *w*, to be cut, so that the wheel rests on the flange *x*; then over the wheel drop the flange or collar *x′* (of the same diameter as *x*); over the shorter part of the axis of wheel *w* place the hollow cone *y*: bring the gallows over the cone; screw down screw 5 just sufficiently tight to hold the gallows in its position, but not to set the wheel *w* fast; remove the pin *k* from the plate P P, and cause the latter to revolve rapidly by the hand or otherwise; the wheel *w* will in all probability be far from concentric with the plate, as will also the centre of cone *y*. With the hand slip the wheel *w* or cone *y*, or both, as may be required, together with the upper flange *x′*, as nearly concentric with the plate P P as the hand and eye will enable you in one or two seconds to do; next slide the piece 6 so as to bring the screw 8 to a convenient distance from the wheel *w*, and set fast by screw 7; then by revolving the plate rapidly, and gradually bringing the end of 8 to the edge of wheel *w*, it will be got perfectly concentric; next screw down 5 sufficiently tight to prevent the wheel from moving, and set fast screw 5 by tightening nut 9: the cutter being then adjusted so as to cut the teeth a proper depth, the cutting proceeds as before described. This operation of setting the wheel perfectly concentric will not occupy an experienced hand more than fifteen seconds.

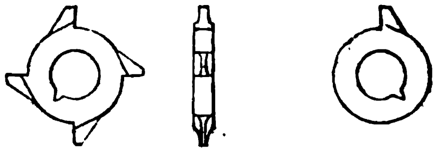
Of the Cutters, and the mode of making and using them.—The cutters vary with the nature of the work to be done, and much depends upon having good ones and well adapted for the purpose. The first kind we shall describe is used for the commonest work, that is, merely for cutting spaces whose sides are parallel through their whole length (in which case the teeth have to be rounded up afterwards), and the cutter is merely a circular disc of steel with teeth on its edge, similar to a circular saw, the two sides being slightly undercut, as seen in the section No. 1: this allows the cutter to pass freely through the metal without clogging, which it would do were the sides parallel. These teeth in the cutter are sometimes made with a file by hand, but they are much better made in the engine. Cutters of this description are generally tempered so low, after having been hardened, as to allow of the teeth being renovated with a 3-square file when they become dull, and answer the purpose well enough for common purposes. A better sort of cutter, and more lasting, is made with from six to sixteen or eighteen teeth, as in No. 2, which gives a side-view and section: these are left very hard, being tempered only to a light straw-colour, and are sharpened with emery and oil on a metal mill or lap; these take much longer making than those first described. When these consist of not more than six teeth, each tooth is generally relieved in direction shown in section No. 3, but not on the sides, by which means the cutter frees itself better, and cuts on its sides to the very root of its tooth, which can be kept sharper and in much better working condition than the foregoing.


No. 1.


No. 2

Cutters are also made having but one tooth, others with two, three, and four; but these are more frequently used when the teeth are to be cut and rounded up at one operation, in which case the side view and section No. 3 will represent the form in which they require to be made to produce the necessary curve for the wheel-teeth; and great nicety is required to produce two curves on each side of the cutting-tooth exactly similar, for unless they are so, the teeth in the wheel cut therewith will have a very unsightly appearance.

No. 3.



It will be necessary to say a few words on the different kinds of work to which the various cutters above described are applicable. No. 1 is used, when tempered low, for soft metal, such as gold and brass and gun-metal; if left hard, they should be sharpened with oilstone dust or very fine emery, and they can then be used for harder metals, such as iron and steel. No. 2 may also be used for the same purposes, but when used for the harder metals should have a greater number of teeth, from 20 to 30 not being too many in a cutter of three-quarters of an inch in diameter. In general, the harder the metal to be cut the greater the number of teeth required in the cutter; and with some metals, such as steel and bell-metal, it is requisite to keep the cutter well supplied with oil, and in all cases where hard metals are under operation the cutter should have a slow motion. Cutters with from one to six teeth may revolve from 10,000 to 20,000 times in a minute in cutting the softer metals, and those with 10 to 20 teeth from 5000 to 8000 or 10,000; in fact, cutters with few teeth cannot be used for the harder metals with advantage, and the others should not have more than from 60 to 100 revolutions in a minute. These observations apply to cutters whose diameter is about three-quarters of an inch; if the cutters are larger, they must have a proportionably less number of revolutions. Cutters are sometimes made for cutting steel, and indeed for all the metals, having very fine teeth, from 200 to 300 in the inch; but the use of them is now almost obsolete: in fact, the process approximates very closely to filing, and such cutters may be regarded as circular files. One great disadvantage is that the keen edges are soon lost, and they cannot be renovated without softening.

Wheel-cutting is one of those operations in which much depends upon the manual dexterity and judgment of the operator; for it sometimes happens that steel, one of the hardest metals, may be cut with a more rapid motion, and a less number of teeth in the cutter, than is stated above; but it is only when the metal is of a particularly mild quality, or has been prepared especially for the purpose by softening. The following mode of softening the steel to be cut is a very good one, and may be frequently adopted with great advantage:—Envelope the articles in a mass of loam, clay, or lime, with sufficient moisture to make it adhesive, taking care that the articles to be softened have a considerable thickness of the material all round them. Heat the mass gradually to a blood-red heat; keep it at this heat as long as convenient, and let it remain in the fire to cool gradually as the fire goes out, after which the articles may be removed, and will be found more uniform in texture and easier to be cut than before being subjected to the operation. In making cutters, as well indeed as any other edge-tools, the susceptibility of receiving and retaining a keen edge will be considerably increased by subjecting the steel to great condensation, by cold hammering, previous to the process of hardening, and more especially if the scale left after forging be first removed with a file. Harden in water, but do not heat your steel too hot; for every degree that steel is heated above its hardening point deteriorates its quality.

WHEEL MANUFACTURE. The simplest form of wheel that can be used for any purpose is that of a plain circular disc, such as might be procured by a transverse section of the trunk of a tree of tolerably regular form. Solid wooden wheels are still occasionally used in machinery, but if large they are usually formed of two or three thicknesses of planking fastened together, with the grain crossing in various directions. Wooden wheels for millwork, when not required to be solid, usually have the periphery formed of segments, the inner sides or edges of which are left straight. The periphery may consist of three thicknesses of planking, each composed of six or eight such segments; and if the three thicknesses are properly break-jointed, a wheel of considerable strength may be thus produced. The arms, or radii, of the wheel are fitted to the inner or straight sides of the segments by bolting or other modes of fastening. Wooden wheels are occasionally morticed into their shafts or axes; but a preferable plan is to use four arms, arranged in two pairs crossing at right angles, and halved into each other in the centre, where their intersection leaves a square opening for the shaft. This opening should be somewhat larger than the shaft itself, and the difference of size should be made up by the insertion of wedges, which afford the means of adjusting the wheel perfectly true upon the axis. In very large wheels, such as water-wheels, two complete sets of clasp arms, one on each side of the wheel, are used. In mounting face-wheels it is not unusual to add stays or braces from the back of the wheel to a point at some distance along the shaft, to resist the tendency of the trundle or pinion to force the wheel out of its true position at right angles with the shaft. Hornbeam is considered to be the best kind of wood for the cogs or teeth of wheels.

In modern machinery cast-iron has almost entirely superseded the use of wood for cog-wheels of every description. If they do not exceed eight or ten feet in diameter, they may be cast in one piece; but if above that size it is desirable to form them into two or more parts, because of the difficulty of cooling a very large casting without unequal contraction. Where the diameter does not exceed twelve or fourteen feet, the rim may still be formed in one piece, and the centre and arms in another, the two to be united by bolts; but when those dimensions are exceeded, a further subdivision is necessary. The rim may then be cast in three segments, the box or centre in one piece, and the arms in several pieces, each terminating in a rib forming half the thickness of an arm, for convenience of bolting together. Large iron wheels are adjusted accurately on their axes by wedges or keys; but small ones may, in many cases, be adjusted by turning the periphery in a lathe after mounting.

Carriage-wheels are those in which the greatest ingenuity of construction is called for, as they are exposed to strains far greater for their size and weight than almost any others. The peculiar nature of these strains requires not only that the wheels be made exceedingly strong, but also that they possess a degree of elasticity sufficient to enable them to bear the violent concussions to which they are continually exposed, without risk of fracture or without the starting of any of their numerous joints. An ordinary carriage-wheel consists of the *nave*, a cylindrical block of wood, usually elm, which forms the centre of the wheel, and is pierced longitudinally with a hole to receive the axle; the *spokes*, which are radiating arms framed into the nave at equal distances; and the *felloes*, which are circular segments framed on to the outer extremities of the spokes, and forming collectively the periphery or rim of the wheel. The external surface of the felloes is usually protected by a covering of iron, called the *tire*, which may either be put on in several pieces, or *strakes*, the joints of which are made to alternate with those of the felloes, or in a single piece, forming a *hoop-tire*. The simplest form in which such a wheel as here alluded to could be formed, would be that in which the spokes would stand at right angles with the axis, and would form a flat or plane figure when the wheel is viewed edgewise; but such a wheel would be ill adapted to meet the lateral shocks to which a carriage-wheel is exposed. The more common form is that called the *dished*-wheel, in which the centre or nave is made to fall back a little from the plane of the felloes, so that the face of the wheel is not flat, but slightly concave. The elasticity of this form is a very great recommendation. It possesses also this advantage: that if the axle be slightly bent downwards towards its extremity, so as to bring the spokes of the lower half of the wheel into a nearly vertical position, which will enable them to bear the greatest possible weight, the upper half of the wheel will have such an inclination outwards as to leave more room for the body of the carriage, and to throw particles of dirt, caught up in its revolution, away from it. Very strong wheels are occasionally made in a double-dished form, or with the spokes alternately inclining outwards and inwards from the felloes, so that the centre or nave of the wheel forms the base of a pyramid of which the felloe forms the apex; but such wheels are very deficient in elasticity, and consequently will not bear much concussion. In ordinary dished wheels the spokes are arranged in two sets, being alternately more and less inclined or dished; and in some cases every alternate spoke is set absolutely straight or square with the nave. The dished form of wheel, together with the bending of the axle, involves some increase of axle friction, and also, if the wheel be wide, the use of a conical tire, which cannot possibly roll in a straight line without a degree of rubbing friction most injurious to the road, and which also increases the draught. Some years ago the use of conical wheels for waggons, combined with the inordinate breadth of tire encouraged by injudicious legislation, was carried to a most absurd extent, and broad-wheeled waggons were used which were far better adapted for grinding stones into dust and mud than for the purpose of locomotion. This extravagance, however, is now seldom seen.

The ordinary mode of making a coach-wheel is as follows. The piece of elm for the nave is turned in a lathe to the proper size and shape, and is hollowed within to receive the axle. It is then fixed in a groove, and holes are chiselled out for the reception of the ends of the spokes. There is nothing but the practised eye of the workman to guide him in making these holes in the proper position for producing the *dishing* of the wheels;—half of the spokes are near one end of the nave, and half near the other, and the holes have to be regulated accordingly. The pieces of oak for the spokes are shaped by hand: a small cutting tool, called a *spoke-shave*, being the chief instrument employed. One end of each spoke is formed into a tenon to fit the mortice-hole in the nave. The spokes are fixed into the holes by driving with a mallet, and are finally shaped after fixing. The rim being formed of several *felloes*, and each felloe being large enough to receive the ends of two spokes, the pieces of ash to form them require to be wrought into segments of curves; this is done by means of pattern-boards and various cutting tools. The felloes are drilled with holes to join them together by means of dowels, with other holes to receive the ends of the spokes.

Few mechanical operations of equal complexity, and requiring an equal amount of precision, have received so little aid from machinery as the manufacture of carriage-wheels; though wheels made by machinery are said to be superior in truth, firmness, and durability to any others. In ordinary wheels the neatness and strength are increased by the application of a hoop of iron to each end of the nave, to enable it the better to resist the strain of the spokes. The spokes, which are usually formed of oak saplings, are wrought into the proper form after being driven into the nave, and are usually cut to a narrow edge in front to lighten their appearance. Wheels have been made with the periphery in one or two pieces, bent into the required form after being softened by boiling and steaming; but the plan has not been found successful, because, among other disadvantages, the wood is injured by the long boiling required. In ordinary coach-wheels, from 4 feet 8 inches to 4 feet 8 inches high, there are fourteen spokes; and in fore-wheels, which are about a foot lower, there are commonly twelve spokes; and the usual arrangement is to have half as many felloes as there are spokes. The introduction of solid or hoop tires is a great improvement upon the former system of wheel-making, as it affords the means of binding the whole of the wheel together with irresistible force. The tire is made very hot, and the wheel is made of such a size as only just to receive it when it is thus expanded; but so soon as the hoop is brought into its proper place, water is thrown upon the wheel to cool the tire, and to prevent the wood-work from catching fire, and the result of the sudden contraction of the hoop is to compress the felloes, and to force each spoke into a slightly curved form, so that when complete the wheel forms a flat dome-shaped figure, admirably adapted, by its combined strength and elasticity, for the purpose for which it is designed. The tire is further secured, after cooling, by a few pins driven through it and the felloes, and riveted inside the latter.

Having found, during his experiments on steam locomotion upon common roads, that wheels of the ordinary construction were not strong enough for his purpose, Mr. Hancock contrived and patented a wheel in which the nave is abandoned altogether, and the inner ends of the spokes are formed into wedges which abut against each other, and form a kind of arch surrounding the axle-box. They are firmly secured in their places by an iron plate on each side of the wheel, and a bolt passing through each spoke. Though too rigid for very rapid motion, this wheel is exceedingly strong, and its simplicity of construction forms a great recommendation.

The rapid motion of railway carriages, coupled with their great weight, so greatly increases the effect of such concussions as must occur on even the smoothest road, that wooden wheels have been fonud utterly unsuitable for them. Cast-iron wheels have been much used on colliery railways, and in some cases where rapid motion is required; but while they may be made abundantly strong, as far as direct pressure is concerned, their brittleness renders them very unsuitable for passenger carriages. Many ingenious plans for the combination of wrought-iron and cast-iron in the same wheel have been devised; but while some of these have been brought into operation, wheels entirely composed of wrought-iron have been by far the most generally adopted. The facility with which that material may be worked into form has led to endless variety of plans, some of which are highly ingenious, for combining the requisite degrees of strength and elasticity. In some wheels the annular space between the central boss or nave and the rim is filled up by a series of elliptical loops, formed of thin bars of iron, abutting against each other; in others there are spokes, but instead of consisting of single rigid bars, each consists of two halves, having a slight degree of curvature. By these and similar contrivances elasticity is insured without dishing the wheels, which would, for railway carriages, be inconvenient. In some cases a portion of the annular space above described is filled with segmental blocks of wood, resembling the felloes of a common wheel; but while this arrangement claims some advantages, its appearance is very inferior to that of the light and often elegant wheels formed entirely of wrought-iron. One kind of iron wheel which claims notice is that patented by Mr. Theodore Jones. These wheels may be compared to double-dished wheels in general appearance, but their principle is very different. They consist of an iron rim pierced at intervals with conical holes, the largest apertures of which are on the outside; two sets of round rods or spokes, with pyramidal heads to fit in the conical holes of the rim, the two sets radiating or inclining alternately inwards and outwards, like the spokes of a double-dished wheel; and a cast-iron nave, which is formed hollow, with holes to receive the inner ends of the spokes, which are secured by nuts screwed on to them within the nave. The peculiarity of this construction is, that instead of the weight resting almost entirely, as in a common wheel, upon those spokes which happen to be below the nave, it is, as it were, suspended by means of the rods or spokes which are above the nave, from the top of the wheel, the rim of which is considered as an inflexible arch. On this account the wheels are called *suspension-wheels*; and as the strength of wrought-iron to resist tension is far greater than its strength to resist compression, a wheel on this principle may be made to bear a much greater load in proportion to its bulk and weight than any other.

As an example of railway-wheels, we may advert to that of Messrs. Hollis & Lee. It is built together in four parts, of which each comprises two spokes, a quadrant of rim, and one fourth part of the nave. The nave thus formed is square. The rim-pieces are a continuation of the spokes, bent round to a curve, and fastened at the spoke ends by tenon and mortice joints.

Patent *noiseless* wheels have been made with tires of india-rubber, and with various contrivances for ensuring durability while obtaining elasticity and noiselessness; but they have not come extensively into use.

The wheels used by cutlers, lapidaries, seal-engravers, and glass engravers, under the names of brush-wheels, buff-wheels, cloth-wheels, composition-wheels, crocus-wheels, emery-wheels, lap-wheels, &c., are mostly made of metal or wood, coated with some other substance at the edge. Their manufacture needs no description.

WHETSTONE, a smooth flat stone used for *whetting* or sharpening edged instruments by friction. Whetstones, which are sometimes called *hones*, are made of various kinds of hard close-grained stone, and are moistened, when in use, with either oil or water. The latter is preferred by some, for giving a keener edge to cutting instruments; but as it allows closer contact between the stone and the metal, it does not appear so well adapted for producing a very smooth surface. The proper use of a whetstone involves a degree of skill and dexterity which can only be obtained by much practice.

WHEY. [Cheese.]

WHIG. This term, like that of Tory, was adopted as a term of reproach, although its origin is by no means certain. North, in his 'Examen,' says it "was very significative as well as ready, being vernacular in Scotland (from whence it was borrowed) for corrupt and sour whey." In point of fact, *whig*, according to the Scottish lexicographers, is not whey, but the slightly acidulated serum of butter-milk.

Quite a different account from this, however, is given by Burnet, in his 'History of his Own Time,' under the year 1648. That writer says, "The south-west counties of Scotland have seldom corn enough to serve them round the year; and the northern parts producing more than they need, those in the west came in the summer to buy at Leith the stores that come from the north; and from a word *whiggam*, used in driving their horses, all that drove were called *whiggamors* and, shorter, the *whiggs*. Now, in that year, after the news came down of Duke Hamilton's defeat, the ministers animated their people to rise and march to Edinburgh; and they came up marching on the head of their parishes, with an unheard-of fury, praying and preaching all the way as they came. The Marquis of Argyle and his party came and bearded them, they being about 6000. This was called the whiggamors' inroad; and ever after that all that opposed the court came in contempt to be called *whiggs*; and from Scotland the word was brought into England, where it is now one of our unhappy terms of distinction."

Probably this is the true origin of the name Whig, and that it was really its previous application to the Scotch Covenanters which led to its revival as a designation for the opponents of the court in England in 1679. Kirkton, in his 'History of the Church of Scotland from the Restoration to 1678' (edited by C. K. Sharpe, Esq., 4to., Edinb., 1817), says, under the year 1667, "The poor people, who were in contempt called Whiggs, became name-fathers to all that owned one honest interest in Britain, who were called Whiggs, after them, even at the court of England: so strangely doth providence improve man's mistakes for the furthering of the Lord's purposes."

With regard to the party opinions of the Whigs, it is scarcely necessary to add anything to what has been stated under the word Tory. The Whigs of the last century and a half are generally viewed as the representatives of the friends of reform or change in the ancient constitution of the country, ever since the popular element became active in the legislature, whether they were called puritans, nonconformists, round-heads, covenanters, or by any other name. Down to the Revolution of 1688 the object of this reform party was to make such change; since that event, at least till recently, it has principally been to maintain the principles of the change then made. Of course, however, this party, like all other parties, has both shifted or modified its professions, principles, and modes of action within certain limits from time to time, in conformity with the continual variations of circumstances, and has seldom been without several shades of opinion among the persons belonging to it in the same age. These differences have been sometimes less, sometimes more distinctive; at one time referring to matters of apparently mere temporary policy, as was thought to be the case when the Whigs of the last age, soon after the breaking out of the French Revolution, split into two sections, which came to be known as the Old and New Whigs; at another, seeming to involve so fundamental a discordance of ultimate views and objects, if not of first principles, as perhaps to make it expedient for one extreme of the party to drop the name of Whig altogether and to call itself something else, as we have seen the Radicals do in our own day. All parties in politics indeed are liable to be thus drawn or forced to shift their ground from time to time; even that party whose general object is to resist change and to preserve what exists, although it has no doubt a more definite course marked out for it than the opposite party, must still often, as Burke expresses it, vary its means to secure the unity of its end; besides, upon no principles will precisely the same objects seem the most desirable or important at all times. But the innovating party, or party of the movement, is more especially subject to this change of views, aims, and character: it can, properly speaking, have no fixed principles; as soon as it begins to assume or profess such, it loses its true character and really passes into its opposite. Accordingly, in point of fact, much of what was once Whiggism has now become Toryism or Conservatism, the changes in the constitution which were formerly sought for being now attained; and, on the other hand, as new objects have presented themselves to it, Whiggism has, in so far as it retains its proper character, put on new aspects, and even taken to itself new names.

WHIRLING-MACHINE is an apparatus invented by Mr. Robins for the purpose of determining the resistance of the air against bodies moving with velocities less than those for which the resistance can be determined by the Ballistic pendulum.

It consists of a brass cylinder, 2 inches in diameter and about 6 inches long, which is fitted in a frame so as to be capable of turning freely with its axis in a vertical position between the base of the frame and a horizontal plate of wood or metal which is supported above the base by four small pillars. The axle of the cylinder, which is of steel, passes through that plate, and terminates about 4 inches above it. To this is attached horizontally, and immediately upon the plate, a thin arm of wood or metal about 4 feet long, and formed with what is called a feather edge on each side: to the extremity of this arm is affixed the object which is to be used in the experiment, and a wire proceeding from the top of the steel axle to the extremity of the arm serves to prevent the latter from bending by its weight.

A silk line made fast at one end to the surface of the cylinder is in part wound round the latter; the line then passes over a pulley fixed in a vertical position at the opposite extremity of the machine, and to its lower end is attached some given weight: the descent of the weight causes the cylinder, and consequently the object at the extremity of the arm above mentioned, to revolve about the vertical axis during the experiment. The weight at the end of the line being acted on by gravity descends at first with an accelerated motion, and consequently the circular movement of the object at the extremity of the bar is also accelerated; but after a few revolutions the resistance of the air against the object becomes very nearly equal to the weight of the descending body, and from that time the descent of the weight and the revolving motion of the object become, as to sense, uniform. When this uniform or terminal velocity is obtained in any experiment, the descending weight evidently expresses the amount of the air's resistance together with the inertia of the machine.

An instrument of this kind was much used by Dr. Hutton, of Woolwich, during the years 1786 and 1787, in his researches concerning the resistance experienced by military projectiles in passing through the air; and the objects which this mathematician applied at the extremity of the revolving arm were hemispheres of pasteboard. Any one of these he could at pleasure dispose so that either its convex or plane surface might be resisted by the air: there was also provided a flat plate of lead equal in weight to the hemisphere employed, which could be fixed to the arm when the hemisphere was removed, for the purpose of ascertaining the resistance opposed by the air to the motion of the arm itself.

The radius of the circle described by each hemisphere in its revolution is measured from the axis of the cylinder to the centre of the sphere, of which the revolving object is the half, and the radius of the cylinder is measured from the same axis to the middle of the silk line passing round the surface: let the latter radius be represented by r, and the former, when any one of the hemispheres is applied, by R. The time is marked by a stop-watch at the end of each revolution, and the differences between them are taken for the times of the revolutions. After a few revolutions the differences are very nearly constant; and a mean of ten or twelve of these nearly constant differences may be considered as the time of revolution, when the motion is uniform in consequence of the equality of the resistance and inertia to the weight of the descending body; let this weight be represented by W.

In order to discover the resistance due to the inertia of the machine and the action of the air upon the arm (the plate of lead, with its plane in a horizontal position, being fixed at the end of the arm), different weights are attached to the silk line, till some one is found which causes the arm to revolve uniformly in the same time as the hemisphere may have been observed to revolve when its motion was uniform. This weight, which may be represented by w, is evidently the equivalent of that resistance and inertia; and the difference $W-w$ is the value of the air's resistance against the anterior surface of the revolving hemisphere only. The velocity of the latter is measured by the length, in feet, of the arc described by its centre in one second, and the weight or resistance $W-w$ is supposed to be applied at the circumference of the cylinder, to which the silk line is a tangent. This term must consequently be multiplied by $\frac{r}{R}$, in order to reduce it to the value of that which would be equivalent to it if applied at the centre of the revolving object.

From a mean of numerous experiments with a hemisphere whose diameter was 6·375 inches, and which revolved with velocities varying from 3 feet to 20 feet per second, Dr. Hutton found that the resistance of the air against the flat side was to the resistance against the convex side as 2·48 to 1: by theory it should be as 2 to 1 only. From experiments made with hemispheres of different magnitudes, also with a whole sphere, a cone, and a very short cylinder, it was found that the resistance experienced by similar surfaces (the velocities varying from 10 feet to 20 feet per second) were nearly proportional to the surfaces, increasing a little above that proportion with the greater surfaces; and that the resistances on the same surface varied, at a mean, with the 2·04 power of the velocity, gradually increasing with the increasing velocities. When a hemispherical or conical surface was acted on by the air, the resistance was less than that which was experienced by a plane surface of equal diameter; but the sharper surface had not always less resistance than one which was round: the convex surface of a hemisphere, for example, experienced less resistance than that of a cone, contrary to the result of theory. The resistance on the base of a cone was to the resistance on the convex surface as 2·3 to 1: by theory it should be as 4 to 1. The resistance on the base of a short cylinder was less than that on the base of a cone, though the areas were equal; also, on account of the different manner in which air acts on the posterior surfaces, the base of a hemisphere experienced less resistance than that of a cone, and the convex surface of a hemisphere less than that of a whole sphere of equal diameter.

The whirling-machine invented by Ferguson is a frame or box of wood, containing a wheel about 2 feet in diameter, on each side of which is a pulley about 6 inches in diameter; the axes of all are in vertical positions, and, by strings passing over the wheel and pulleys, the latter are made to revolve on turning the wheel by means of a handle. The machine was intended to exhibit, in a popular manner, the principal effects of centripetal or centrifugal forces, when bodies revolve in the circumferences of circles.

On the axle of each pulley there is fixed, at its middle point, a bar of wood in a horizontal position, and on this a small plate or carriage of brass is made to slide easily along two horizontal wires extending from the centre to one extremity of the bar: a silk line attached to this plate passes under a small brass pulley near the centre of the bar, and over a similar pulley fixed in a brass frame, about 6 inches above the first pulley; the line is afterwards attached to a brass plate or carriage, which is capable of sliding up or down in the brass frame, according as the first plate moves from or towards the centre, along the wires on the horizontal bar. A given weight is placed on this first carriage at any distance from the centre, and the pulley, to whose axle the bar is fixed, is made to revolve by turning the handle on the axle of the wheel: then, on placing such a weight on the carriage in the brass frame as will just allow the former weight to recede in consequence of the centrifugal force which that weight with its carriage acquires by the revolution, the weight in the frame, including that of its carriage, is to be considered as the equivalent of the centrifugal force.

For example, let the two pulleys be of equal diameters, and let each be made to carry on its axle a horizontal bar with a sliding plate or carriage: then, if a weight of 6 ounces, including the carriage, be placed at 3 inches from the centre of motion on one bar, and 2 ounces, including the carriage, on the other bar, at 9 inches from its centre of motion; upon making the two bars revolve rapidly, the centrifugal forces will cause any equal weights on the carriages in the two brass frames to rise to the tops of those frames at the same instant. Here the velocities of rotation are represented by 3 and 9, and the weights by 6 and 2, so that the ratio compounded of the velocities and masses is one of equality; and this is considered as verifying the proposition that if bodies revolve in circular orbits, the centrifugal forces are equal when the products of the masses and velocities are equal. Again, let the diameter of one of the pulleys be twice as great as that of the other, so that when the bars are placed on the axles and are made to revolve by turning the wheel, the angular velocity of one may be half the angular velocity of the other: then, if any equal weights, for example, be fixed on the carriages which slide on the two bars, at equal distances from the centres of motion, and if there be placed on the carriages in the brass frames above those centres, weights, including those of the carriages, such that the weight above the larger pulley may be one-fourth of that which is above the smaller pulley; the centrifugal forces arising from the revolutions will allow these weights to be raised at the same instant, proving that both the revolving bodies are retained in circular orbits. Here the angular velocities of the revolving bodies are as 1 to 2, and the weights in the frames, which represent the centrifugal forces, are as 1 to 4; and the experiment shows that when equal bodies revolve in equal circular orbits, the centrifugal or centripetal forces are to one another as the squares of the angular velocities.

It is easy to understand that such experiments may be varied so as to exhibit all the phenomena of circular movements.

WHIRLPOOL, a place in a river, or in the sea, where in consequence of obstructions from banks, rocks, or islands, or the opposition of winds and currents, the waters acquire a revolving motion.

The agitation of the waters which is constantly observed near Messina, and which is usually designated the whirlpool of Charybdis, is now well known to be unaccompanied by any vortiginous motion by which vessels might be absorbed, and is, rather, an incessant undulation of the water. The agitation is said to exist in several different places at the same time, within the circumferences of circles whose diameters, when the wind is moderate, do not exceed 100 feet, and is caused by the wind acting obliquely on the rapid current which sets towards the faro, or lighthouse, from the north during six hours, and from the south during the next six hours, and so on alternately; the changes taking place respectively with the rising and setting of the moon. Spallanzani, who was rowed over the spot when the wind was light, experienced no danger, though the boat was much tossed by the waves: he was informed however that when the wind is high, the swelling of the waves is more violent and extensive, so that small vessels which are driven within the limits of the agitation may be sunk by the waves breaking over them, and large ones may be driven on the Italian shore, where they are sometimes wrecked on the rock of Scylla. The dashing of the waves on the hollow rocks about Cape Peloro produces a noise which is said to resemble the barking of dogs; and it is probable that these sounds gave rise to the fable that a female monster surrounded by ferocious dogs and wolves lay there in wait to devour the mariners who might be wrecked on the coast.

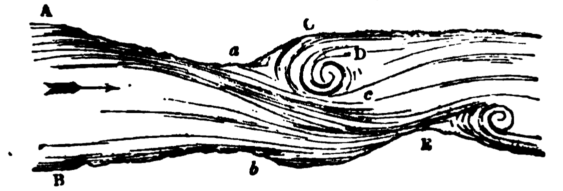
Some of the descriptive particulars of the Galofaro, the supposed Charybdis [CALABRIA, col. 236, in GEOG. DIV.], just given, are derived from Captain (now Admiral) W. H. Smyth's account of Sicily and its islands. We now add the following, as given, from that work, in the author's subsequent memoir on the Mediterranean, pp. 181, 182:—"To the undecked boats of the Rhegians, Locrians, Zanoleans, and Greeks it must have been formidable; for even in the present day small craft are sometimes endangered by it, and I have seen several men-of-war, and even a 74-gun ship (*the Queen, bearing the flag of Rear-Admiral Sir Charles Penrose*), whirled round on its surface; but by using due caution there is generally very little danger or inconvenience to be apprehended. The Galofaro appears to be an agitated water, of from 70 to 90 fathoms in depth. . . . . . It is owing probably to the meeting of the harbour and lateral currents with the main one, the latter being forced over in this direction by the opposite point of Pezzo. This agrees in some measure with the relation of Thucydides, who calls it a violent reciprocation of the Tyrrhene and Sicilian seas; and he is the only writer of remote antiquity I remember to have read who has assigned this danger its true situation and not exaggerated its effects. Many wonderful stories are told respecting this vortex, particularly some said to have been related by the celebrated diver, Colas, who at last lost his life here. I have never found reason, however, during my examination of this spot, to believe one of them. The formation of the Tangdora shoals, stretching out on each side of the little kind of bay off which the Galofaro is situated, is probably owing to the eddies of Charybdis."

The Maelstrom, between the islands of Mosker and Warae on the coast of Norway, appears to be of a similar nature: the tide there forms a current which runs with violence alternately from north to south, and in a contrary direction; and when this is opposed by the winds, there is created an agitation of the water, the sound of which is heard at sea to the distance of many leagues. At high and at low water, in moderate weather, ships pass through the strait without danger; but during strong gales they keep at a considerable distance in order to avoid being drawn into the current, in consequence of which they might founder among the waves, or be otherwise destroyed. Whales and fish, it is said, are often found dead on the shores, against which they have been dashed by the violence with which the waters rush through the channel.

Whirlpools are produced among the Orkney Islands by the actions of winds and currents; but boats, it is said, pass over the spots in safety, a log of wood or a bundle of straw previously thrown into the water being sufficient to arrest its revolving motion.

The circular or spiral motion of the water, which constitutes a whirlpool or eddy in a river, is produced by flexures of the banks or contractions of the bed; in consequence of which the current, instead of continuing parallel to the general direction of the river, is turned obliquely towards the middle: the particles of water between this oblique current and the bank by which the waters from the upper part of the river are reflected, are acted upon by forces in different directions; and the centrifugal force resulting from the curvilinear motion causes the centres of the whirlpools to be on a lower level than the general surface of the water in the river.

Let A B be the distance between the two banks of a river at a part where a contraction of the bed begins to take place, and let *a b* be the narrowest part of the channel, in the vicinity: the water in part arrested by the bank A *a*, rises above the general level of the water in the river at that place, and being reflected, will be made to take an oblique direction, as *a c*; at the same time, the velocity in the contracted section becomes, by the laws of hydrodynamics, greater than that of the river above A B. Then the particles of water within the space *a* C *c*, rushing towards *a c*, the surface within that space becomes depressed, and the particles about D descend into the space by their gravity. It follows that there is a constant tendency of the waters from D towards C *a*, and from C towards *a c*, besides the current in the direction *a c*; and by the action of the forces in these directions the revolving motion takes place. Whirlpools are continually being formed in this manner, and are carried to some distance down the river by the general current.



Whirlpools may in like manner be formed at the same time, below *b*, on the opposite bank of the river, if this should have a similar form to the bank between A and C; or the stream *a c* may be reflected from E, should there be a contraction at that place, and whirlpools may be formed in the enlargement beyond, as shown in the diagram. Precisely in like manner are formed the whirlpools or eddies at the shoulders of the piers of a bridge, when the breadth of the river is so much contracted as to cause its surface above the bridge to be considerably higher than the surface below. Under these whirlpools the bed of the river must evidently sustain less pressure than takes place on the parts about them: consequently, the water under the bed, acting hydrostatically upwards, may lift up the earth and stones, and thus undermine the piers; or it may blow up the piles driven for the formation of dams. By this cause the accidents which occur in hydraulic operations are frequently produced.

Inequalities in the depth of the bed of a river must evidently give rise to vertical whirlpools by the reflexion of the water from the ascending slopes; the particles then take an oblique direction upwards, so as to rise like a wave above the general surface: also, a sudden depression of the bed will produce a vertical whirlpool in the lower part, nearly as the horizontal whirlpools before mentioned are supposed to have been formed.

WHIRLWIND. [Wind.]

WHISKEY. The preparation of this spirit is sufficiently described under Distillery; while the trade and the taxation connected with it are noticed under Wine and Spirit Trade. The name is derived from the Irish word *uisgue*, 'water;' and *usquebaugh*, the name of a cordial at one time in much request, is derived from the Irish *uisgue beatha*, 'water of life.' We may here remark, among the discoveries of the rectifiers, that a few drops of creasote and fusel oil will give a whiskey flavour to two or three gallons of good London gin, if long kept.

WHISPERING PLACES are vaults or galleries in which the sound of words uttered with a low voice is augmented, so as to become audible at a considerable distance from the speaker.

When the air is agitated by any impulse, as the utterance of a word at some spot, the undulations extend spherically in every direction, and thus give rise to perceptions of sound which diminish rapidly in intensity as the distance of the auditor increases; but if the impulse be given at one of the extremities of a tube, it is evident that the undulations will be prevented from spreading laterally, and the whole effect, augmented in consequence of the condensation of the particles of air in the tube, will be experienced: in this manner may be explained the increase of the intensity of sound in a trumpet or a speaking-pipe. [Pipe.] A like effect takes place in a less degree when sound ascends from the bottom of a deep well, or when words are uttered at one extremity of a long corridor or passage in a building. It is said that if a pin be dropped into the well in Carisbrooke Castle, in the Isle of Wight, the sound produced when it strikes the water is distinctly heard at the mouth: the well is above 200 feet deep. The sound of words spoken near the surface of any long wall is similarly augmented in the direction of the length of the wall; the latter, in some measure preventing the undulation from being diffused in the atmosphere. The effect in a corridor is frequently increased when the corridor has bends in its length, or when it is smaller at one extremity than at the other.

When the place is in the form of a dome, the undulations of the air, which are produced by a sound emitted near the concave surface, at any part of the base of the dome, are, by continual deflections from every part of the concave surface, transmitted to a point in the base diametrically opposite to that from whence the sound proceeded; and there the waves are concentrated so as to cause the perception of a sound many times louder than that which was emitted.

The whispering gallery in Gloucester Cathedral, which is described in Birch's 'History of the Royal Society,' vol. i., is a passage leading from one aisle to the opposite, behind the east window of the choir: it is 3 feet wide, and about 6½ feet high; its whole length is about 75 feet, and its form on the plan is half an irregular octagon: the walls and ceiling are of freestone, and the latter, which is flat, is unevenly wrought. If two persons are placed, one at each end, near either wall, and one converses with the other in the lowest whisper, the words are as distinctly heard as if the persons were close together. The whispering gallery in St. Paul's Cathedral, London, is that which surrounds the base in the concave surface of the interior dome: here a person speaking in a whisper near the surface of the vault is heard distinctly by a person also near the surface and at the opposite extremity of a diameter, persons in any other part not being able to hear the sound.

WHITE ARSENIC. A popular name for arsenious acid. [Arsenic. *Arsenious Acid.*]

WHITE CANONS, so called from their habit, which was a white cassock with a rochet over it, a long white cloak, and white caps, belonged to the Premonstratensian Order of the Augustine Monks. They were brought into England shortly after 1140, and settled first at Newhouse in Lincolnshire. They had in England a conservator of their privileges, but were nevertheless often visited by their superiors of Premonstre, who raised great contributions out of them, as the generals or foreign heads of the Cluniacs or Cistercians also did from their order, till restrained from it by the parliament of Carlisle, in the last year of Edward I., 1307. They, however, continued under the jurisdiction of the Abbot of Premonstre and the general chapter of the order till 1512, when they were exempted from it by a bull of Pope Julius II., confirmed by King Henry VIII., when the superiority of all the houses of this order in England and Wales was given to the Abbot of Welbeck, in Nottinghamshire. Tanner reckoned about thirty-five houses of this order in England. (Tanner, *Notit. Monast.*; Dugd., *Mon. Angl.*)

WHITE FLUX. A substance used in metallurgical operations on a small scale. It consists chiefly of carbonate of potash, and is prepared by calcining bitartrate of potash (*cream of tartar*) with twice its weight of nitrate of potash.

WHITE GUNPOWDER. A composition consisting of three parts of chlorate of potash, one part of white sugar, and one of ferrocyanide of potassium. The ingredients must be *separately* reduced to fine powder and then intimately mixed in a wooden mortar with a wooden pestle. Its explosive force is much greater than ordinary gunpowder, and the ingredients may be kept separate until the powder is wanted, which would prevent all danger of the accidental explosion of large quantities. Its manufacture is, however, attended with considerable risk, as it explodes by friction and percussion, and several serious accidents have already resulted even from its preparation on a small scale. Contact with a minute drop of sulphuric acid causes it instantly to explode.

WHITE LEAD. [Lead.]

WHITE PRECIPITATE. [Mercury. *White precipitate.*]

WHITE SWELLING, a disease of the joints, so called on account of the unaltered colour of the skin. Under this term are included nearly all those diseases of the joints which are the result of chronic inflammation in the bones, cartilages, or membranes constituting the joint. These inflammations are constantly attended with swelling, which is circumscribed; the part is sometimes hard, resisting the pressure of the fingers, and thus leading to the impression that the bone is swollen and diseased; or it may be elastic, and yielding to pressure; or so soft as to produce the impression of the presence of fluid. Sometimes these swellings are attended with no pain; at other times pain is one of the earliest symptoms, and is constantly present, and greatly aggravated by the motion of the limb. In some cases the motions of the joint are but little impeded, whilst in others they are entirely destroyed. These general symptoms however admit of distinction, and several forms of white swelling can now be traced to different parts of the joint as their seat.

Amongst old writers these diseases have been described under the names of *spina ventosa, fungus articuli*, lymphatic tumour, and other names. A common division of these diseases is also into rheumatic and scrofulous, according as they were supposed to have their origin in a rheumatic or scrofulous state of the system. The more active were referred to the former and the chronic to the latter. Many other distinctions are founded more upon the age, temperament, and constitution of the patient, than upon essential differences of the disease. The following are the diseases of the joints which are generally denominated white swellings.

1. *Inflammation of the Synovial Membranes.*—This disease may be either acute or chronic. When acute, the skin is generally red, and the joint very painful and tender. It commences with pain at one particular spot, and in a day or two after, swelling takes place. The swelling may be felt at first to undulate, from the effusion of fluid into the membrane; but this becomes less evident as the disease advances, from the thickening of the membranes and also from the effusion of lymph. The swelling always assumes the form and direction of the synovial membranes. In a few days the disease subsides altogether or assumes the chronic form. When the inflammation is chronic from the beginning, the pain and tenderness are much less, so that the patient is able to walk about without much difficulty. There is little or no fever, the skin retains its natural colour, the swelling increases only slowly, and the symptoms are rendered worse by exposure to cold and exertion. In these cases, although the effused fluid may at length become absorbed, the synovial membrane remains thickened, and swelling and stiffness of the joint are the consequence, constituting a very common form of white swelling. The causes of this disease are both constitutional and local. It may arise as an effect of phlebitis, gout, rheumatism, syphilis, or mercury; or it may be produced by sprains, contusions, wounds, dislocations, or fractures of the heads of the bones.

The treatment of this disease must vary according as it is acute or chronic, or dependent on local or constitutional causes. In the acute and local form of the disease perfect quietude must be insisted on, cupping and leeches to the part should be had recourse to, with saline purgatives and diaphoretics. When the skin is tense, fomentations and poultices may be used; but where not, cold lotions will be best. In the early stage of the chronic form, leeches and cold lotions to the part may be applied and perfect quietude enjoined. In the latter stages, counter-irritants may be used, such as blisters, the savine cerate, ointment of tartarised antimony, &c. When persons are well enough to move about, the joint should be kept from movement by strapping it with soap-plaster, or covering it with a bandage or a cap of leather or other material made to fit tight. Bathing with cold salt water, or pouring on the part cold water may be recommended. For the removal of the stiffness, shampooing, the vapour-bath, or friction with the hand, may be employed. When the inflammation arises from rheumatism or syphilis, the treatment should be the same as for those diseases.

2. *Pulpy Thickening of the Synovial Membrane.*—This disease generally occurs in young persons between the ages of sixteen and twenty-five, and is mostly confined to the knee-joint. There is not much pain in the joint, but swelling and rigidity come on slowly. The joint on being touched appears to have fluid in it. This disease goes on sometimes for years, till at last it destroys the joint; and unless the limb is amputated, hectic symptoms ensue and destroy the patient. This disease consists in a total disorganisation of the synovial membrane, which is converted into a brownish or lightish brown pulpy substance, varying from a quarter of an inch to half an inch in thickness. In its advanced stages the cartilages, bones, and ligaments of the joint become implicated in the disease.

The well-marked cases of this disease must be looked upon as incurable, and only amputation will give a chance of relief. In mild or doubtful cases the only plan that seems to offer success is perfect quietude of the joint, which may be secured by pasteboard or other splints, or by soap-plaster. The general health should be attended to, and local applications made according to the symptoms. Inflammation should be subdued by leeches, and gentle counter-irritants may be kept constantly applied.

3. *Ulceration of the Cartilages.*—This disease occurs chiefly in children or adults under the middle age. It is frequently a consequence of the preceding diseases, but often occurs alone, although in its progress it may involve the whole joint. The joint in which it is most frequently seen is the hip, producing the greater amount of the diseases known by the name of hip-joint disease. When it occurs in the knee, it differs from inflammation of the synovial membrane by the pain at the commencement of the disease being slight, and its going on increasing in intensity. The pain is also present sometimes four or five weeks before any swelling is perceived. The swelling, when it does occur, arises from inflammation of the cellular tissue outside the joint, and often appears much larger than it really is, from the previous wasting of the leg from want of use. In many cases an effusion takes place into the synovial membrane and increases the swelling. In the progress of the disease abscesses form, having fistulous connections with the synovial membrane and the surrounding inflamed tissue. As the cartilaginous tissue is renewed with difficulty, the most favourable termination of this disease is generally attended with anchylosis of the joint.

In the treatment of this disease rest is essential; whatever moves the limb, affects the diseased cartilage. The limb may be placed in splints, or bandaged up with soap-plaster, or perfect quietude of the joint may be secured by M'Intyre's fracture-splint, which has the advantage of being easily removed for the purpose of making applications to the part affected. Where the joint is hot, cold lotions and leeches may be applied; but where it is cool, counter-irritants, blisters, issues, moxas, antimonial ointment, or croton oil. On the continent the actual cautery is recommended. For the swelling and rigidity which so constantly remain, relief may be sought in the cold douche, shampooing, or friction with the hand.

4. *Scrofulous Disease of the Joints, beginning in the Bones.*—At one time all white swellings were supposed to involve the bones, and this on account of the apparent enlargement of the bones of the affected joint. That this is not the case the existence of the above forms of disease proves, but even the fact on which the supposition was founded is not correct. So far from the bones being always enlarged in these cases, there are only a very few on record in which dissection has shown the bones to be enlarged. The bone has been supposed to be swelled from the hardness of the part and its size: but the former arises from the natural texture of the parts, and the latter is made to appear greater by contrast with the wasting diseased limb. But the bones are subject to disease which begins in their cancellous texture. The phosphate of lime is removed from them or deposited in less quantity, and a yellow caseous substance is secreted in its place. The heads of the bones are altogether weakened and softened, and deposits of bony matter of an irregular form are found on their outside. Whilst this change is going on the patient experiences pain; the knee, which is the joint it most commonly attacks, swells; the motions of the joint are affected, and it becomes more or less contracted, so as to prevent it being straightened. In the course of time matter is formed in the cavity, and makes its way out by ulceration through the synovial membrane, or abscesses form on the outside of the joint. Sometimes sinuses occur, and run to a considerable extent from the joint under the fascia, or between it and the skin.

This condition of a limb is generally connected with a scrofulous constitution, and the more decided the scrofulous disposition, the more difficult will the disease be to treat. However, whatever may be the state of the constitution, this must be attended to primarily in the treatment of these cases. [Scrofula.] The local treatment must be the same as for other cases of white swelling. Quietude of the joint should be secured on some of the plans previously proposed; and as there is a constant tendency to anchylosis, care should be taken if possible that the anchylosis occurs in a position most convenient for using the limb. Counter-irritants will be found of great utility in these cases, such as blisters, antimonial ointment, and croton oil. Care, however, must be taken that they are not employed whilst there is a tendency to inflammatory action; and, on the other hand, the means that are employed, such as leeches, cold lotions, &c., for an increased activity of the part, should be immediately abandoned when that activity ceases. When the morbid process has been arrested, shampooing, friction, and pouring water on the part from a height, should be had recourse to for the purpose of strengthening it. The abscesses which form in these cases should be opened early; if left to themselves, they often leave ulcerations which are difficult to heal.

(Cooper, *First Lines of Surgery; Surgical Dictionary;* Brodie, *Pathological and Surgical Observations on Diseases of the Joints.*)

WHITE VITRIOL. [Vitriol.]

WHITING. An impure carbonate of lime, prepared by grinding and then washing chalk, so as to separate the coarser and heavier particles from the lighter and finer ones, which latter are then collected into masses and dried.

WHITLOW is an inflammation affecting the phalanges of the fingers, and generally proceeding to suppuration. The part attacked, however, is not confined to the fingers; the same disease may also appear in the toes. *Paronychia* and *Onychia* are terms which are used to express the same disease. Surgical authors describe several forms of whitlow, or paronychia, according to the textures which the inflammation attacks. Thus it may be situated in the skin, the cellular tissue under the skin, the tendons or theca of the fingers or toes, in the periosteum, or it may be seated in the cellular tissue under the nail. When the inflammation is confined to the skin, vesicles appear, which quickly advance to suppuration, and the case requires little attention. When the subcutaneous cellular tissue is affected, the case is more serious, though it seldom extends: there is throbbing pain of the part, and there may be severe constitutional disturbance, and suppuration is a less or greater length of time in taking place. The whitlow under the nail differs from this form only in situation. In these cases only the cellular tissue under the cutis is affected, and no great danger or mischief is to be apprehended from the whitlow. When, however, the inflammation extends to the tendons, periosteum, and bone, then the symptoms are very severe; and by extending from the finger affected, up the arm, and involving a large extent of surface, fatal consequences have sometimes been the result. The commencement of this form of whitlow is indicated by a burning, shooting, throbbing pain of the finger, with a varying degree of constitutional disturbance. Sometimes the febrile symptoms are very violent; and when the arm is involved, delirium and other alarming symptoms come on. At first there is no perceptible change in the part affected: at length, however, slight swelling comes on, which may extend up the arm, even to the axilla. In these cases a small quantity of matter is collected under the flexor tendon of the finger, or under the periosteum, in which latter case the bone is mostly affected with caries.

Whitlows may be caused by some external injury, such as a prick from a needle, pin, thorn, or other pointed object, or they may arise spontaneously. The latter not unfrequently occurs in young persons who are apparently in a good state of health.

In the treatment of whitlow the inflammation can rarely be subdued before it proceeds to suppuration. It may however be tried, and cold lotions and local bleeding, with general antiphlogistic treatment, will sometimes subdue the inflammation. When matter is formed, the best thing that can be done is to get rid of it as soon as possible, and this must be done by cutting down quite upon the seat of inflammation and pain. When matter is formed, ease is immediately given by its being discharged; and even should an incision be made before suppuration has taken place, it will alleviate the symptoms. Where matter is formed extensively under the tendons, free incisions should be made wherever it is collected. Where caries of the bone exists in whitlows, it may be sometimes a question as to whether amputation is not the most effectual treatment. Where whitlow occurs under the nail, the matter may be discharged either by an incision under the nail from the side, or by scraping the nail and making the incision from above.

WHITSUNTIDE is probably a contracted form of White Sunday tide or time. In the early ages of Christianity the favourite seasons for administering the rite of baptism were Easter Sunday, the anniversary of the resurrection of Christ, and Whitsunday, that of the Jewish feast of Pentecost, when the apostles were "baptised with the Holy Ghost and with fire," and they themselves commenced their public ministry by baptising three thousand persons. As emblematic of the spiritual purity which the rite of baptism is supposed to confer, those who received it were clothed in white, and the day is hence conjectured to have received its name of White Sunday (*Dominica alba*). Other etymologies more remote and less probable have been given. The rite of baptism was performed in early times on Easter Sunday eve and Whit Sunday eve, that is, on the preceding Saturday evening, when there was a special ceremony of hallowing the font. In a volume of manuscript homilies in the Harleian Library, in the British Museum, No. 2371, it is stated, that "in the begynnyng of holy chirch, all the children weren kept to be crystened on thys even, at the font hallowyng; but now, for enchesone that in so long abydynge they might dye without crystendome, therefore holy chirch ordeyneth to crysten at all times of the yeare; savo, eyght dayes before these evenyns, the chylde shalle abyde till the font hallowing, if it may savely for perrill of death, or ells not."

Our ancestors seem to have indulged to excess in the season of Whitsuntide in all kinds of exercises and amusements, for which many of the parishes provided the needful stimulus, and out of which they claimed their due share of profit: for this purpose a house or barn, which was called the church-house, was set apart, and a quantity of ale was brewed, which was called Whitsun Ale, or Church Ale, and was sold to the parishioners who came there to feast and drink, and gamble, and the profits were applied to the repairs of the church, and sometimes to charitable and other purposes.

(Brady's *Clavis Calendaria;* Strutt's *Sports and Pastimes* by Hone; Brand's *Popular Antiquities*, by Ellis.)

WIFE; HUSBAND and WIFE. Many of the legal incidents attached to the relation of husband and wife, or, as they are called in our law books, *Baron* and *Feme*, have been already noticed under their several heads: the mode of contracting the connection may be found under MARRIAGE, and of dissolving it, under DIVORCE; the provision for the wife out of her husband's real estates, made by the common law and modified by statutes, is treated of under DOWER; and the right derived from the same source by the husband to a life interest in his wife's real estate if he survives her and has had a child capable of inheriting, under COURTESY OF ENGLAND; the voluntary provision which may be made for the husband, the wife, and the offspring of the marriage, is discussed under SETTLEMENT and JOINTURE; and the nature of the property which the wife has, if not independently of her husband, concurrently with him, is described under PARAPHERNALIA and SEPARATE PROPERTY. The article PARENT AND CHILD shows what little right the law has conceded to the wife with regard to the children of the marriage. It is, therefore, only necessary now to give a general sketch of the subject, so as to bring the separate parts under one view, and to supply such information as may not yet have been given.

The common law treats the wife (whom it calls a feme covert, and her condition coverture) as subject to the husband, and gives him leave to exercise over her reasonable restraint, and it has been said to inflict on her moderate chastisement. The wife may now, however, obtain security that the husband shall keep the peace towards her. It looks on the husband and wife in most respects as one person, having only one mind or will, which is exercised by the husband. Hence a wife cannot sue separately from her husband for injuries done to her or to her property, or be sued alone for debts, unless her husband shall have abjured or been banished the realm; or she has obtained a judicial separation, or protection for her earnings, in consequence of his having deserted her; or unless where, by particular customs, she is permitted to trade alone, as in London; but even here the husband should be joined as defendant by way of conformity, though execution will issue against the wife alone. For injuries to the wife's person or property the remedy is by a joint action, or sometimes by the separate action of the husband. Hence again not only can they not in any case, by the common law, contract with or sue one another; but compacts made between them and all debts contracted towards each other when single (unless those made in consideration or at least in contemplation of marriage) are made void at the common law by their union. This rule does not, however, apply to debts due from the husband to the wife in a representative character, as administratrix or executrix, for instance. They cannot make grants one to another to take effect during the joint lives; nor can the wife, excepting in the exercise of a power, devise lands to her husband or to any other person; but the husband may devise to his wife property to be enjoyed by her after his death. They can give evidence, however, touching one another, except in criminal cases, or proceedings arising out of or relating to adultery. In criminal prosecutions, however, founded on injuries committed by either party on the person of the other, the injured party may (*ex necessitate rei*) be a witness. Neither can rob the other in the contemplation of law. The property of both is, with some modifications, liable to the debts of either, and with the person of his wife the husband takes the liability to her debts contracted before marriage; but those debts are only recoverable during the wife's life. If she dies before him, he is relieved from that responsibility, whatsoever fortune he may have had with her, excepting that he must apply to the discharge of such debts any assets which are received by him as his wife's administrator. As the law considers the wife to be under the perpetual control of her husband, it relieves her from responsibility for offences short of murder and high treason committed at his instigation—the evidence of that instigation being his presence during the commission of the offence. For the same reason all deeds executed by her are void; unless in fulfilment of powers vested in her or under the guarantee of certain solemnities to ensure her free agency. A disposition by a woman of her property after the commencement of a treaty for marriage, without the privity and concurrence of her intended husband, is deemed by courts of equity to be fraudulent, and will be set aside after the marriage as an injury to her husband; a will made before marriage is also revoked by the subsequent marriage of the party making it. [WILL AND TESTAMENT.]

This legal identity cannot be dissolved, whether in the eyes of the civil or ecclesiastical courts, by any voluntary act of the parties. Thus no deed of separation, unless it contains an immediate and certain provision for the wife, and no advertisement or other public notification will relieve a husband from the liability to provide his wife with necessaries fitting to her rank in life (the question of fitness being decided by a jury), or consequently from the duty of paying the debts contracted for such necessaries, if she has been driven from his house by his misconduct. On the other hand, a wife cannot recover at law from her husband from whom she lives apart any allowance which he has contracted with herself to pay her in consideration of the separation, if he desires that their union should be renewed. Nor again is a deed of separation a sufficient answer to a suit promoted by either party for restitution of conjugal rights; far less is it an answer to the charge of adultery committed either before or after separation. (Haggard's 'Consistory Reports,' i. 143.)

But this union may be dissolved, when sought for, *bonâ fide*, by either party without collusion with the other, as a remedy for that other's conjugal offences [DIVORCE]; and the dissolution relieves the husband of his responsibility for his wife's debts contracted after the decree is pronounced, or, in case of his wife's adultery, contracted after the discovery of the adultery and the consequent separation; for if no separation takes place, or if the husband abandons his usual residence to his wife and her paramour, he will be liable to debts contracted by her with tradesmen who are ignorant of the facts. So too, by the common law, a husband is not liable for the debts of his wife contracted after she has quitted his house without sufficient cause, and he has given particular notice to the tradesmen that he will not pay her debts. Still less is he liable for debts contracted while she is living in open adultery. On the other hand, where the separation or divorce is obtained by the wife on account of the cruelty or adultery of her husband, the court continues on him the duty of maintaining her (if her separate property will not enable her to live according to her rank in life) by requiring him to make her an allowance proportionate to his means. [ALIMONY.] The common law recognises this right of the wife in such circumstances to an allowance under the name of her estovers; and grants her a writ for the recovery of them; but this remedy is now never resorted to.

Such is the general and leading principle of the common law; but this supposed identity of person, of interest, and of property by no means involves equal rights.

The theory of the law is, that the husband has over his wife's personal property absolute control, and over real property a control modified partly by the general rules of descent, partly by statute, partly by the decisions of courts of equity, which always lean to the protection of the wife's property and the maintenance of any contract or provision made, whether by her husband or others, for her benefit, even so far as to admit a suit of the wife in the name of her next friend against the husband for injuries done by the latter to her property or for the recovery of rights withheld by him. To this end they interpret the Statute of Uses, as giving the wife, by the interposition of trustees, independent rights to property and control over it. Thus although she cannot take by direct grant from her husband, she may avail herself of such a grant by him to trustees for her benefit, and generally she may take by devise and by descent directly; and by settlement, or by grant through the intervention of trustees; she may herself be a trustee, and (although that position has been controverted) she may devise her trusts. Again, the common law vests in her husband not only her personal property (excepting her paraphernalia), but her chattels, real or leasehold interests; yet if a settlement has not been made on her expressly in consideration of her fortune, those portions of her personal property which consist of securities for money or beneficial contracts, and her chattels real, survive to herself, provided the securities have not been realised, and the chattels real have not been aliened, during his life by her husband; to arrears of rent due on the wife's separate estate, the husband is, however, entitled by statute 32 Henry VIII. c. 37. [Choses in Action.] Nor does the settlement deprive her of this right with regard to things in action acquired subsequently to the execution of the settlement, unless it expressly reserves to the husband future as well as present personalty. If a husband requires the intervention of a court of equity for the purpose of reducing into possession his wife's property, the court will require him to make on her a settlement proportionate to the benefit which he derives. Usually one-half of the fund is settled upon the wife and children, but the court takes all the circumstances into consideration, especially whether any settlement already exists. The adultery of the wife deprives her of her equity (unless she has been a ward of court married without the consent of the court); but her delinquency will not induce the court to vest the whole of her property in her husband, because he does not maintain her. The court will secure the property for the benefit of the survivor and the children. On the other hand, in case of the cruelty of the husband or his desertion of his wife, the court will award to her and her children not only the whole principal, but the interest of the property in question. On the same principle, if the husband is insolvent, the court will grant to the wife out of her trust property an allowance usually equal to half the proceeds of that property. The interest which the husband takes in his wife's real estate of which she is seised in fee vests the profits in him during her life, but it gives him no power over the inheritance. By the common law a husband might alien his wife's real estate, or lease it for her life or that of the tenant, and she was left to her remedy if she survived him, or her heir at law had his remedy if the husband survived: if they neglected that remedy, the alienation by the husband was good; but by the 32 Henry VIII., c. 28, the wife or her heir may enter and defeat the husband's act. By that statute the lease of lands held by a man in right of his wife, or jointly with her, is good against husband and wife if executed by both; the lease may be for years or for life, but it must relate to land usually leased, it must not be by anticipation or in consideration of a fine; it must reserve a fair yearly rent to the husband and wife; and the husband is restricted from aliening or discharging the rent for a longer term than his own life. If, however, the wife receives rent after her husband's death upon any lease of her estate improperly granted by him, she confirms that lease. A wife's copyhold estates are forfeited to the lord by any such acts of her husband as are ruinous to the estate (for example, waste), as destroy the tenure (for example, an attempt to convert it into a freehold), or otherwise deprive the lord of his rights, as a positive refusal to pay rent or perform service. But courts of equity will relieve the tenant when the forfeiture is not wilful or can be compensated.

The husband may mortgage his wife's real property during their joint lives and during his life in addition, if he survives her, and become tenant by the courtesy; if the wife joins in that mortgage, and recognises it after her husband's death, she will be bound by it; but she may, if she thinks fit, repudiate it. Before fines were abolished, her levying a fine rendered a mortgage a good security against her and her heirs; and since the act abolishing that form of assurance, a deed acknowledged by her as the act prescribes effects the same object. [Fine of Lands.] A mortgage made by a wife of her estate for the sole benefit of her husband, and not to discharge a debt of her own, gives her a right at equity to compensation out of his assets.

Such are the principal rights which a husband acquires in his wife's property, and the limitations of those rights. On the other hand, the common law gives to her if she survives him an estate for life in a third part of all such estates of inheritance as he was *solely seised of during* the marriage, and as any children of the marriage might possibly have inherited. [Dower.] That right of dower may be forfeited in various ways, and it may be defeated by a provision for her, made before marriage, in the shape of jointure. [Jointure.] Since the stat. 3 & 4 Wm. IV. c. 105, in marriages subsequent to 1st January, 1834, dower does not attach unless the *husband died possessed*; and it does accrue on estates disposed of by the husband during his life or by will, while it may be defeated by a declaration of the husband by deed or will, that his estates are not to be subject to dower.

The Statute of Distributions (22 & 23 Car. II. c. 10) gives to the widow of an intestate husband (if her claim has not been barred by settlement) one-third of his personal property where there is issue of the marriage living, and one-half where there is none. Marriage revokes powers of attorney previously granted by the wife, and disables her from granting them; but it does not disable her from accepting such a power, or from acting on one granted to her before coverture. She may too be attorney for her husband. She cannot bequeath her personal estate by will unless under a power, or with the consent of her husband.

The separate property of the wife has been already treated under that head. [Separate Property; Pin-money.]

There remains only the separation of husband and wife; which may be by deed or by decree of the Court for Divorce and Matrimonial Causes. The ecclesiastical courts considered all deeds of separation and all covenants in the nature of such deeds to be void. The courts of law, however, not only have supported such deeds against the husband, but have enforced a covenant made by him with his wife's trustees to pay her an annuity as a separate maintenance in the event of their future separation, with the approbation of the trustees. But courts of equity will not interfere to enforce such deeds, though by a strange inconsistency they will enforce the husband's covenant for a separate maintenance if made through the intervention of trustees, and indeed in certain rare cases if made between the husband and wife alone. Nor is the adultery of the wife a sufficient answer to her claim to the separate maintenance. The separation by decree is either a judicial separation or a divorce. A wife when deserted by her husband may obtain an order to protect her earnings from him or his creditors, and she will then be able to contract as if she were a *feme sole*. But when the desertion of the husband extends over a period of two years, or when he treats her with cruelty, or commits adultery, the wife may obtain a judicial separation. [Separation.] When, again, the husband commits incestuous adultery, or to adultery adds the crimes of bigamy or rape, cruelty or desertion for two years, or is guilty besides the adultery of an unnatural offence, the wife may obtain a dissolution of the marriage. [Divorce.]

WIFE. (*Scotland.*) The moveable or personal estate of a husband and wife is under the administration of the husband; according to the phraseology of the law it is called "the goods in communion," because on the dissolution of the marriage by the death of either party it falls to be so divided that if there be issue of the marriage a third, and if there be no issue a half, goes to the nearest of kin or to the legatees of the deceased, whether husband or wife, the remainder being the property of the survivor. During the continuance of the marriage the husband's right as administrator is in all respects equivalent to the right of a proprietor, and whether the common property has been acquired by himself or by the wife, it is entirely at his disposal, in so far as that disposal is intended to have effect during his lifetime. His right of bequeathing it is limited by the Scottish law of succession. [Will.] As the husband has the administration of the wife's property, he is responsible not only to the extent of the goods in communion, but personally, for the wife's obligations, whether contracted before or after marriage. No suit can be brought against a married woman unless the husband be made a party. The wife cannot of herself enter into a contract exigible by execution against the goods in communion and the person of her husband, unless in certain cases in which by general law or by practice she holds an agency. To this effect she is *præposita negotiis domesticis*, and whatever debts she incurs for household purposes are debts against the husband; but the husband may discharge himself from responsibility for debts so incurred by obtaining an "inhibition" against her. A wife's agency may be extended like that of any other agent; but it does not extend, without special authority, to the borrowing of money.

Heritable property (a term nearly equivalent to that of real property in England) belonging to either party is in the administration of the husband. He can however grant no lease of his wife's heritable property, to last beyond his own life, without her concurrence. On the other hand, from the date of the proclamation of the banns all deeds granted by the wife are null if they do not bear the husband's concurrence. His right of administration, including the necessity for his concurrence in the wife's deeds, may be excluded by his resigning his *jus mariti* in an antenuptial contract of marriage, or by the special exclusion of the *jus mariti* in the title of any estate conveyed to the wife. Every deed executed by a wife is presumed to have been executed under the coercion of her husband, and may be set aside unless the wife ratify it by oath before a magistrate.

A separation of married parties may take place either by judicial interference or voluntary contract. Personal violence or acts physically or morally injurious on the part of the husband, will justify a judicial separation at the suit of the wife, in which an alimentary allowance is awarded to her proportioned to his means. A voluntary separation may take place by mutual agreement, but in such a case an alimentary allowance will not be awarded unless it has been stipulated for. The husband whose wife is either judicially or voluntarily separated from him ceases to be responsible for the debts incurred by her after the date of the separation. Her own property is liable to execution for her obligations, but not her person, unless her husband be living out of Scotland, in which case it has been decided that a wife transacting business on her own account is liable to diligence against her person, or arrest and imprisonment. The husband has the uncontrolled custody of the children of the marriage during pupillarity. The court of session will interfere for their protection in the case of their personal ill-usage, or of danger of contamination, but not on the ground of a special estate being settled on a child by a third party.

On the dissolution of a marriage by the death of either party, an anterior question to that of the distribution of the property is, whether the marriage was permanent. A permanent marriage is one which has lasted for a year and part of a day, or of which a living child has been born. In the case of dissolution by death of a marriage not permanent, there is a question of accounting, and the property of the parties is, as nearly as circumstances will permit, so distributed as it would have been had no marriage between them been solemnised. In the case of a permanent marriage, the moveable property is divided as above stated, the survivor getting a half, if there is no issue, and a third if there is issue. Of any real property in which a wife dies infeft, if there have been a living child born of the marriage, and if there is no surviving issue of the wife by a former marriage, the widower enjoys the life-rent use; this is called "the courtesy of Scotland." A widow enjoys the life-rent of one-third part of the lands over which her husband has died infeft, by way of "Terce." The distribution of the property, personal or heritable, may be otherwise arranged by antenuptial contract, or equivalents to the property to which a party would succeed may be made by the settlements of the deceased.

On the dissolution of marriage by divorce, the offending party forfeits whatever provisions, legal or conventional, he or she might be entitled to from the marriage; and the innocent party, at whose instance the suit of divorce is brought, retains whatever benefits, legal or conventional, he or she may have become entitled to by the marriage. It follows that when the divorce proceeds at the suit of the wife, she obtains, at the date of the decree of divorce, the provisions which, as above, she would be entitled to on the death of her husband; and that, on the other hand, if the suit be at the instance of the husband, the wife not only loses her right to such provisions, but forfeits to the husband whatever property she may have brought into the goods in communion.

WIFE, ROMAN. [Marriage, Roman.]

WILL. [Free-Will.]

WILL AND TESTAMENT. Before the passing of the 32 Hen. VIII. c. 7, commonly called the Statute of Wills, and the 34 & 35 Hen. VIII. c. 5, there was no general testamentary power of freehold land in England, but the power of making a will of personal property appears to have existed from the earliest period. Yet this power did not originally extend to the whole of a man's personal estate; but a man's goods, after paying his debts and funeral expenses, were divisible into three equal parts, one of which went to his children, another to his wife, and the third was at his own disposal. If he had no wife or no children, he might bequeath one half, and if he had neither wife nor children, the whole was disposable by will (2 Bl. 'Comm.,' 522, Mr. Kerr's edit.; Fitzherbert, 'Nat. Brev.,' 122). The law, however, was gradually altered in other parts of England, and in the province of York, the principality of Wales, and in the city of London more lately by statute, so as to give a man the power of bequeathing the whole of his personal property. At present by the 1 Vict. c. 26, for the amendment of the law with respect to wills (whereby the former statutes there enumerated, with respect to wills are repealed, except so far as the same acts or any of them respectively relate to any wills of estates *pur autre vie* to which this act does not extend), it is enacted that it shall be lawful for every person to devise, bequeath, and dispose of, by his will, executed as required by that act, all real and personal estate which he shall be entitled to either at law or in equity at the time of his death. Great alterations have been introduced into the law of wills by this statute; but as it does not extend to any will made before the 1st of January, 1838, it is necessary to consider the law as it stood previous to the act.

In general all persons are capable of disposing by will of both real and personal estate who have sufficient understanding. The power of the king to make a will is defined by the 39 & 40 Geo. III. c. 88, s. 10. By the former Statute of Wills, married women, persons within the age of twenty-one years, idiots and persons of non sane memory, were declared incapable of making wills of real estate. These disabilities also applied to a bequest of personal estate, except that infants of a certain age, namely, males of fourteen and females of twelve, might dispose, by will, of personalty; and that by the 12 Car. II. c. 21, s. 8, a father under twenty-one might, by a will attested by two witnesses, appoint guardians to his children. But, by the second section of the Wills Act, no will made by any person under the age of twenty-one years is valid; and no will made by any married woman is valid, except such a will as might have been made by a married woman before the passing of the new act. The disability of a married woman is not absolute. She may make a will of her personal property if her husband consents to that particular will, and it will be operative if he survive her. The validity of a lunatic's will depends upon the state of his mind at the time of making it. Persons born deaf and dumb are presumed to be incapable of making a will, but the presumption may be rebutted by evidence. Blindness and deafness alone do not produce incapacity. Devises of lands by aliens are at least voidable, the crown being entitled, after office found, to seize them in the hands of the devisee, as it might have done in those of the alien during his life.

Previously to the act 1 Vict. c. 26, the general power of testators was subject to exceptions. Customary freeholds and copyholds were not within the Statute of Wills, and therefore, unless where devisable by special custom, could in general be passed only by means of a surrender to the use of a will. By the 55 Geo. III. c. 192, the want of a surrender was supplied in cases where it was a mere form, but the act did not apply to cases where there was no custom to surrender to the use of a will, nor to what are called customary freeholds. A devisee or surrenderee of copyholds could not devise before admittance, though an heir-at-law might. Conditions were not devisable, nor were rights of entry or action, nor contingent interests when the person to be entitled was not ascertained: lands acquired after the execution of the will also did not pass by it; but by section 3 of 1 Vict. c. 26, the power of disposition by will extends to all real and personal estate, and to all estates, interests, and rights to which the testator may be entitled at the time of his death, though acquired subsequently to the execution of his will. There is no restriction as to the persons to whom devises or bequests may be made, except under the 34 & 35 Hen. VIII. c. 5, which forbids devises of lands to bodies politic and corporate. Exceptions to this statute have been introduced by the 43 Geo. III. c. 107, and 43 Geo. III. c. 108, which authorise devises of lands to the governors of Queen Anne's Bounty, and for the erection or repair of churches or chapels, the enlargement of churchyards or of the residence or glebe for ministers of the Church of England. Alienage cannot be properly called an incapacity to take by devise, as the devised lands remain in the alien till office found, when they vest in the crown. By the 9 Geo. II. c. 36, no lands or personal estate to be laid out in the purchase of or charged on land can be given to any charitable use by way of devise. [Mortmain.] By the 40 Geo. III. c. 98, no disposition of property can be made by will or otherwise, so as to accumulate the income for a longer period than for twenty-one years after the death of the settlor, or during certain minorities [Accumulation]; and by what is called the rule against perpetuities, no property can be settled by deed or will so as to be inalienable for more than a life or lives in being, and twenty-one years afterwards.

Before the 1 Vict. c. 26, wills of personal estate might even be nuncupative, that is to say, might be declared by the testator without writing before witnesses, provided they were made in conformity with the directions contained in the 19th section of the Statute of Frauds (29 Car. II. c. 3). A will of freehold lands of inheritance was required to be executed in the manner prescribed by the 5th section of the Statute of Frauds, which required it to be signed by the party devising, or by some other person in his presence and by his express direction, and to be attested and subscribed in the presence of the devisor by three or more credible witnesses. The term "credible," which gave rise to much discussion under the old law, is omitted in the 1 Vict. c. 26, and it is enacted in the 14th section that no will is to be void on account of the incompetency of any attesting witness. By the 15th section gifts to attesting witnesses or their wives or husbands are declared void. This is an extension of the 25 Geo. II. c. 26, which related only to wills which at that time required the attestation of witnesses, that is to say, to wills of real estate. The words as to wives or husbands are new. The signature of the testator was not required for the validity of a will of personalty or of copyholds, whether the instrument was in his own hand-writing or in that of another. But by the 9th section of 1 Vict. c. 26, no will, whether of real or personal estate, is to be valid unless it be in writing, and signed at the foot or end by the testator or by some person in his presence and by his direction; and such signature must be made or acknowledged by the testator in the presence of two or more witnesses present at the same time, and such witnesses must attest and subscribe the will in the presence of the testator, but no particular form of attestation is necessary. Section 10 enacts that all appointments made by will are to be executed in the manner above prescribed, and are to be valid when so executed notwithstanding the non-observance of any other ceremonies required by the power under which the appointment is made. By the 11th and 12th sections, it is declared that the act is not to affect the wills of soldiers on actual service, or of mariners at sea, which are to remain subject to the particular provisions made respecting them by the 11 Geo. IV. and 1 Will. IV. c. 20. Questions formerly arose as to what was a publication of a will, but section 13 of 1 Vict. c. 26 enacts that no other publication shall be requisite than execution in the manner prescribed.

It is the rule in England, that a will of lands is regulated by the law of the country in which the lands are. The place where and the language in which such a will is written are unimportant: the locality of the lands is the only point to be considered. A will made in France and written in French, of lands in England, must contain expressions which when translated into English would properly designate the lands in question, and must be executed according to the forms required by the English law. Lands in England which belong to an

English subject domiciled abroad and dying intestate, will descend according to the English law. With respect to personalty, on the other hand, in cases both of testacy and intestacy, the law is different. If a British subject becomes domiciled abroad, the law of his domicile at the time of his death is the rule which the English courts follow in determining the validity of his will and administering his personal property in England, and *vice versâ* in the case of a foreigner dying domiciled in England. Cases sometimes arise in which it is difficult to determine what was the domicile at the time of the death of the party, and consequently what rule is to be followed in the distribution of his personal estate. If an Englishman domiciled abroad has real property in England, he ought on account of the difference of the doctrine with respect to real and personal property, to make two wills, one duly executed according to the English law for devising his real estate, and another framed according to the law of his domicile for the disposal of his personal property.

A will is a revocable instrument. It was an established rule of law that the will of a *feme sole* was revoked by her marriage, but marriage alone was not considered a revocation of the will of a man; though marriage and the birth of a child, whom the will would disinherit, conjointly were admitted by the courts to have that effect, on the ground that these circumstances together produced such a change in the testator's situation, that it could not be presumed he could intend any previous disposition of his property to continue unchanged. By section 18 of the act 1 Vict. c. 26, every will made by a man or woman is revoked by marriage, except a will made in exercise of a power of appointment when the real or personal estate thereby appointed would not, in default of appointment, pass to the heir, personal representative, or next of kin of the appointor. And by the 19th section no will is to be considered as revoked by any presumption of intention on the ground of an alteration in circumstances. By the 20th section no will or codicil is revocable except as above mentioned, or by another will or codicil executed in the manner required by the act, or by a writing declaring an intention to revoke, executed in the same manner, or by burning, tearing, or otherwise destroying the will by the testator himself, or by some other person in his presence, and by his direction, with intent to revoke. By the 21st section no obliteration, interlineation, or other alteration made in any will after execution is to have any effect, except in so far as the words or effect of the will previous to the alteration cannot be made out, unless the alteration be executed as a will, such execution to be in the margin opposite or near to the alteration, or to a memorandum referring to the alteration. By the Statute of Frauds witnesses to a will were required to sign in the testator's presence, but it was not necessary that he should sign in their presence, whereas by section 6 of that act, a mere revocation in writing must have been signed by the testator in presence of the witnesses, but they were not required to sign in his presence. This inconsistency is now removed. The 21st section alters the law as to the effect of obliterations where the words remain legible, and of cancellation by drawing lines across the whole or any part of the will. These acts will now be of no effect unless properly executed and attested. By the 23rd section no conveyance or other act made or done subsequently to the execution of a will of real or personal estate, except an act of revocation, is to prevent the operation of the will upon such estate or interest as the testator has power to dispose of at the time of his death: and by the 24th section every will is to be construed with reference to the real and personal estate comprised in it, so as to take effect as if it had been executed immediately before the death of the testator, unless a contrary intention appear on the will.

Republication of a will is in fact a re-execution of it, being a repetition of the ceremonies required for its original validity: before the act 1 Vict. c. 26, a devise of lands could only be republished by signature and attestation by three witnesses, while with respect to copyholds and personalty a will might be republished without any formal execution, and even by the mere parol acts and declarations of the testator.

The 22nd section of the act provides that no will or codicil, or any part thereof, which shall have been in any manner revoked, shall be revived otherwise than by the re-execution thereof, or by a codicil executed in manner required by the act, and showing an intention to revive the same; and when any will or codicil which shall be partly and afterwards wholly revoked, shall be revived, the revival is not to extend to such parts as had been revoked before the revocation of the whole, unless a contrary intention appear. Under the old law, if a second will or codicil which revoked a former will was afterwards cancelled, the first, if it had been kept undestroyed, was held to be revived. It had previously been determined (4 Ves., 610) that a subsequent codicil, merely for a particular purpose and confirming the will in other respects, did not amount to a republication of parts of the will revoked by a former codicil. This section extends the doctrine to the case where a will had been first partially and afterwards wholly revoked.

Estates or interests in property created by way of executory devise or bequest, that is to say, such as are made expectant on the determination of prior estates in the same property, may be, like estates created by way of remainder in a deed, either vested or contingent. So far as depends upon the nature of the limitations themselves, the same rules are in general applicable to executory devises or bequests as to remainders; but testamentary instruments are not construed with the same strictness as deeds, and in determining the question of vesting or contingency, many considerations, depending on expressions in the will or other circumstances appearing upon the face of it, are admitted as affording presumptions of the intention of the testator. It is impossible here to give any enumeration of the numerous rules which have been laid down on this subject, and which are of course liable to be modified according to the circumstances of each particular case. It may however be observed generally that when a future gift is preceded by a gift of the immediate interest, it is to be presumed that the enjoyment only is postponed, and that the future gift is vested in interest; whereas when there is no gift of the immediate interest, the contrary presumption obtains: and again, that when the enjoyment of a gift is postponed, not on account of circumstances personal to the object of the gift, but with a view to the circumstances of the estate, the gift is to be presumed vested. With respect to pecuniary legacies, some distinctions, borrowed from the civil law, are admitted which have no place as to real estate. One of these distinctions is that where futurity is annexed to the *substance* of the gift, the vesting is in the mean time suspended: but where the *time of payment* only is future, the legacy vests immediately. If however the only gift is contained in the direction to pay, this case is to be regarded as one in which time is annexed to the substance of the gift. When a future gift of a principal sum is coupled with a gift of the interest in the mean time, a strong presumption exists in favour of vesting. It is generally considered that a very clear expression of intention must exist in order to postpone the vesting of residuary bequests, on the ground that intestacy may often be the consequence of holding them to be contingent.

Great changes have been introduced in the law, as to the interpretation of wills by the above-mentioned 24th section of the act, which declares that wills are to be construed to speak as if they were executed immediately before the death of the testator, and by the six following clauses. The 25th section enacts that, unless a contrary intention appear on the will, a residuary devise shall include all estates comprised in lapsed and void devises. This alters the former law, whereby such estates devolved on the heir. The 26th clause enacts that a general devise of the testator's lands shall include copyhold and leasehold as well as freehold lands, unless a contrary intention appear. This also effects a considerable alteration in the law of devises. Formerly neither copyholds (unless surrendered to the use of the will) nor leaseholds would pass by a general devise of lands or other general words descriptive of real estate, unless the testator had no freehold lands on which the devise might operate. Since the statute of the 55 Geo. III. c. 192, which dispenses with the necessity of surrenders in certain cases, copyholds stood upon nearly the same footing as freeholds, in respect to a general devise; but leaseholds still continued subject to the old rule of law. By the 27th section, unless a contrary intention appear, a general devise of real estate and a general bequest of personal estate are respectively to include estates and property over which the testator has a general power of appointment. It was never considered necessary in the execution of a power of appointing real estate, whether general or special, to refer expressly to the power. It was sufficient if the intention to exercise it appeared from a description of the property in the will or by other means. If the testator had no other lands which answered the description, a general devise would have been a good execution of the power; but it was otherwise if he had any other lands which would satisfy the terms of the devise. The enactment applies only when the testator has a general power of appointment. Where the power is limited or special, it seems that the old rule of construction will still hold. As to personal property the rule was, that there must be some reference to the power, on the somewhat unsatisfactory ground that as any person must be supposed possessed of some personalty, there was enough to make a general bequest operative without reference to the property comprised in the power. With respect to devises, it seems that the old rule must still prevail where the power is special or limited. By the 28th section a devise of real estate without words of limitation is, unless a contrary intention appear by the will, to be construed to pass the fee. This clause introduces a very considerable alteration of the old law, under which, in accordance with the doctrine that the heir was not to be disinherited by implication, it was settled that a devise of lands without words of limitation conferred on the devisee an estate for life only, notwithstanding the appearance of a contrary intention in other parts of the will. The 29th section enacts, that in any devise or bequest of real or personal estate the words "die without issue," "die without leaving issue," or "have no issue," or any other words of the like import, shall be construed to mean a want or failure of issue at the time of the death, and not an indefinite failure of issue, unless a contrary intention appear; except in cases where such words mean, if no issue described in a preceding gift shall be born, or if there shall be no issue who shall live to attain the age or otherwise answer the description required for obtaining a vested estate by a preceding gift to such issue. Under the old law, when a testator gave an estate to A and his heirs, and directed that if A died without issue it should go to B, though his meaning in most cases was that B should have it unless A had issue living at the time of his death, the word "issue" was held to comprise descendants of every degree existing at any distance of time, and the consequence was, that where the subject of the devise was real estate, A took an estate tail and acquired the absolute dominion over the property, and where it was personalty the ulterior disposition to B was void for remoteness.

By the 30th section every devise of real estate (not being a right of presentation to a church) to a trustee or executor is to be construed to pass a fee simple, unless where a definite term of years or an estate of freehold less than the fee simple is expressly given to him. And by the 31st section trustees under an unlimited devise to them, when the trust may endure beyond the life of a person beneficially entitled for life, are to take the fee. When the limitation in a will was made to a trustee by way of use, he took the legal estate by the operation of the Statute of Uses, without reference to the nature of the trust. But in other cases the question was determined by the intention of the testator, as collected from the nature of the trust; and the trustee was considered to take only that quantity of estate which the exigencies of the trust required. Such a rule of construction was obviously of very difficult operation, and it was often not easy to determine in whom the fee was vested at any given period, and therefore who were the proper parties to deal with the property and to join in a conveyance of it. The enactments contained in the two last-mentioned sections will in a great measure remedy this inconvenience.

It follows from the nature of wills that the devises and bequests contained in them are liable to failure from the death of the devisee or legatee before the testator. This is called the doctrine of lapse. It applies equally to devises of real estate and to bequests of personalty. It is a general rule that words of limitation to heirs or executors superadded to a gift have no effect in preventing lapse in case of the devisee or legatee dying before the testator, for they are considered not as words of gift, but merely as indicating the legal devolution of the property. When the gift is to several persons as joint tenants, unless all the objects die before the testator, there can be no lapse; for as joint tenants are each takers of the whole, any one existing at the death of the testator will be entitled to the whole. The same is the case where the gift is to a class, unless where the individuals of the class were ascertained before the lapse. Two changes have been introduced into the law of lapse by the new act. The 32nd section enacts that devises of estates tail shall not lapse, but that where the devisee in tail dies during the life-time of the testator, leaving issue, the devise shall take effect as if he had died immediately after the testator, unless a contrary intention appear by the will: and, by the 33rd section, gifts to children or other issue who shall die before the testator, having issue living at the testator's death are not to lapse, but, if no contrary intention appear by the will, are to take effect as if the persons had died immediately after the testator. As a will of personalty operated upon all the property of that kind belonging to the testator at the time of his decease, there could obviously be no intestacy with regard to any part of the personal estate while there was a valid residuary bequest. The same is now true of wills of real estate in which there is a valid residuary devise, so that there is no longer room for many of the questions that arose as to whether the residuary devisee took beneficially or as a trustee, and as to the devolution of real estate directed to be sold.

If an ambiguity exists on the face of a will, or, as it is technically termed, is patent, parol evidence cannot be admitted to remove it, because to admit evidence to explain what the will has left uncertain would be in effect to make a new will by parol. If the ambiguity is not apparent on the face of the will, but arises from circumstances disclosed when an attempt is made to carry the will into effect, it may be removed by evidence of the same nature.

(Jarman, *On Wills*, and Jarman and Sweet's *Notes* to Bythewood's *Precedents, Wills.*)

WILL. (*Scotland.*) The right of bequest in Scotland is confined to moveable or personal property. It does not extend to heritable or real property—which comprehends lands and tenements, fixtures, those appurtenances of a family mansion (such as the pictures, plate, and library) which are called "heirship moveables," the machinery in mines and manufactories, the stock on farms, and every description of security or other right over any of these kinds of property. Settlements may be made of heritable property in the manner which will be described below, but it is a principle of the greatest importance, and one the neglect of which is often productive of the most serious consequences, that no such settlement can be made in the form of a will. All persons of sound mind above the age of puberty (fourteen in males, and twelve in females) may execute wills; and persons under guardianship, as wives and minors who have curators, may do so without the consent of their guardians. The will of a bastard was formerly ineffectual, and the moveable goods of such a person, lapsing to the crown on his death, were distributed by a gift in exchequer; but this peculiarity was abolished by 6 & 7 Will. IV. c. 22. A verbal or "nuncupative" will, if uttered in the presence of two witnesses who bear testimony to it, is valid to the extent of a hundred pounds Scots, or *8l. 6s. 8d.* sterling. A will, sufficiently formal in all points to prove its terms and its date, must be executed in the presence of witnesses and attested.

Where the will is holograph, or written by the granter himself, it does not require to be attested. If the party cannot write, he can execute a will through a notary, who receives authority in presence of two subscribing witnesses to sign for the testator, and describes the transaction in his notarial docquet. A clergyman of the Established Church of Scotland may act as a notary for the signing of a will. It is usual to nominate an executor of the will, but it is not essential to do so; and if there be no one named, an executor is supplied by operation of law. Wills executed by persons domiciled out of Scotland, if they be according to the form which would carry such property in the place where they were executed, will be effectual to convey moveable property in Scotland; but no will, whatever be the law of the place where it is made, can dispose of heritable property in Scotland. The last dated will is the effectual one, and all others are considered as revoked by it in so far as they are inconsistent with it.

The peculiar feature of the law of Scotland out of which arises the circumstance that heritable or real property cannot be bequeathed is, that no deed conveying such property is effectual unless it be expressed in what are called "dispositive terms," or terms making over the property at the moment of the signing of the deed. The peculiarity arose during the time when the holder of a fief could not part with it to another person, unless that person were accepted as a vassal by the feudal superior. But to accomplish the purposes of a virtual bequest, the party grants a conveyance, reserving power to alter, and dispenses with delivery of the deed. The formalities necessary to the execution of wills carrying moveables are necessary to settlements conveying heritable property, but with this difference, that in the settlement of heritable property, if the party cannot write, the deed must be executed by two notaries before four witnesses; and in this case a clergyman cannot act as notary.

No settlement of heritable property to the prejudice of the heir-at-law can be validly granted on a death-bed. Three elements are necessary to constitute the legal exception of death-bed: 1st, that the granter was ill of the disease of which he died when he granted the deed; 2nd, that he died within sixty days after executing it; and, 3rd, that he did not go to church, or to a market, unsupported, during the sixty days.

WILL, ROMAN. A Roman will—called Testamentum, was defined by the jurists of the Imperial period to be "a legal mode of a man's declaring his intention in due form, to take effect after his death."

The power of making a Roman testament only belonged to Roman citizens who were sui juris, a rule which excluded a great number of persons: those who were in the power of another, as sons not emancipated, and daughters; impuberes; dumb persons, deaf persons, insane persons, and others; and, as a general rule, all women. The circumstances under which a woman could make a will were peculiar; and they would require a very particular statement. A male of the age of fourteen years complete, unless under some special incapacity, could make a valid will. A female, so far as respected age only, acquired this capacity on the completion of her twelfth year.

Originally Roman citizens made their wills at Calata Comitia, which were held twice a year for this purpose. It is not said that these wills were made in writing; and it is here assumed that they were made at the Calata Comitia only for the purpose of securing the proper evidence of the testator's intention. If a man died in the interval between two such Comitia without having made his will, he must have died intestate. But wills could also be made in Procinctu, that is, by a soldier under arms and in presence of the enemy. Another mode of testamentary disposition was introduced, apparently for the purpose of preventing intestacy. If a man, says Gaius (ii. 102), had neither made his will at the Calata Comitia nor in Procinctu, and was threatened with sudden death, he transferred, by the form of mancipatio, his familia, that is, his patrimonium, to a friend, and told him what to give to each person after his death: this was called the testamentum per æs et libram, because the transfer was effected by mancipatio. Thus it appears that the testamentum per æs et libram was a formal transfer of the property during the lifetime of the owner to a person who undertook to dispose of it as he was directed. As it was a substitute for the testament made at the Calata Comitia, it is a probable inference that it only differed from the testament made at the Comitia in wanting that publicity. The two old forms of testamentary disposition, adds Gaius, fell into disuse, and that per æs et libram became the common form. Originally the formal purchaser of the testator's estate (familiæ emptor) occupied the place of the heres at a later time; when Gaius wrote, and long before his time, the old form of testamentary disposition was retained as to the familiæ emptor, but a heres was appointed by the will to carry into effect the testator's intention. The formal purchaser was only retained out of regard to ancient custom, and the institution of a heres became necessary to the validity of a will.

The form of testamentary transfer per æs et libram is described by Gaius (ii. 104). Written wills, as already observed, were not necessary, for neither mancipation nor the institution of a heres require a writing. But written wills were the common form during the later republican and the imperial period. Wills were written on tablets of wood or wax; hence the word "cera" (wax) is often used as equivalent to tabula. A Roman will was required to be in the Latin language until A.D. 439, when it was enacted that wills might be written in Greek. A Roman will in the later periods was sealed and signed by the witnesses. The sealing consisted in making a mark with a ring or something else on the wax, and the names were added. The seals and names were on the outside, for, according to the old law, there was no occasion for the witnesses to know the contents of the will. The old practice was for the testator to show the will to the witnesses, and to call on them to witness that what he so presented to them was his will. It was not unusual for a man to make several copies of his will, and to deposit them in some safe keeping. At the opening of the will the witnesses or the greater part, if alive and on the spot, were present, and after acknowledging their signatures the will was opened.

It has been mentioned that, in order to make a Roman will valid, it must appoint or institute a heres. The heres was a person who represented the testator, and who paid the legacies which were left by the will. He stood in the place of the familiæ emptor, or formal purchaser of the property in the old form of will. A heres might be appointed in such words as follow:—"Titius heres esto" ("let Titius be my heres"), or "Titium heredem esse jubeo" ("I will Titius to be my heres"). Generally, all Roman citizens who could make a will could be heredes; but persons could be heredes who could not make a will—slaves, for instance, and others who were not sui juris.

Fraud in the case of wills and other instruments was punished by severe penalties under a Lex Cornelia.

The development of the Edictal or Prætorian law at Rome introduced a less formal kind of will. If there were seven proper witnesses and seven seals, and if the testator had the power of disposition both at the time of making his will and at the time of his death, the edict dispensed with the ceremony of mancipation and gave to the heres or heredes the bonorum possessio. This mode of testamentary disposition existed under the Republic, and, accordingly, a man could either make his will by the civil form of mancipatio, or he might make it after the prætorian form, with seven seals and seven witnesses, without any mancipatio. The form of testamentary disposition by mancipatio was ultimately superseded by the more convenient prætorian form. The legislation of Justinian required several male witnesses of proper age and due legal capacity; and it was sufficient if the testator declared his will orally before these witnesses.

A Roman will, as already observed, was valid if the testator had a disposing power at the time of making his will and at the time of his death. It follows that his will, though made at any time before his death, was sufficient to dispose of all the property that he had at the time of his death. In order to render a Roman will valid, it was necessary that the heredes sui of a man (his sons and daughters were in the class of heredes sui) should either be appointed heredes or should be expressly excluded from the inheritance. A will which was illegal at the time of being made was testamentum injustum; that is, "non jure factum" (not made in due legal form). A will which was justum might become invalid; it might become ruptum (broken) or irritum (ineffectual).

A second will duly (jure) made rendered a former will invalid (ruptum); and it was immaterial whether the second will took effect or not. If it was duly made, it rendered a former will of no effect, and the testator died intestate.

If a testator sustained a capitis diminutio after making his will,—that is, if he lost any part of his status of a Roman citizen which was essential to give him a full testamentary power,—the will became irritum (ineffectual). A prior will might become ruptum by the making of a subsequent will; and such subsequent will might become irritum in various ways; for instance, if there was no heres to take under the second will.

Though a will had become ruptum or irritum, and consequently lost all its effect by the Jus Civile, it might not be entirely without effect. The Bonorum Possessio might be granted by the Prætorian law, if the will was attested by seven witnesses, and if the testator had a disposing power, though the proper forms required by the Jus Civile had not been observed.

The rule of Roman law which required heredes sui to be expressly exheredated applied to posthumous children. If a suus heres was born after the making of the will, and was not recognised as heres or exheredated in due form, the will became ruptum. This rule of law was thus expressed: "adgnascendo rumpitur testamentum." There were also cases in which a will might become ruptum by a quasiadgnatio.

A testament was called Inofficiosum when it was made in due legal form, but not "ex officio pietatis." Thus, when a man did not give the hereditas, or a portion of it, to his own children or to others who were in a near relation to him; and when there was no sufficient reason for passing them by, the person so injured might have an action, called Inofficiosi Querela. The persons who could maintain this action were particularly defined by the legislation of Justinian. If the testamentum was declared by the competent authorities to be inofficiosum, it was rescinded to the amount of one-fourth of the hereditas, which was distributed among the claimants.

The ground of the Inofficiosi Querela is explained by Savigny. ('System des Heutiges Röm. Rechts,' ii. 127, &c.) When the testator in his will passed by persons who were his nearest kin, it was presumed that such persons had merited the testator's disapprobation. If this was not so, it was considered that the testator had by his will done them a wrong, and the object of the action was to get redress by setting the will aside. The main object, however, was the establishment of the complainant's character, to which the obtaining of part of the testator's property was a subsidiary means. The expression Testamentum Inofficiosum occurs in Cicero and in Quintilian; but it is not known when the Inofficiosi Querela was introduced.

A Roman codicil (Codicili, for the word is not used in the singular number till a late period under the Empire) was a testamentary disposition, but it had not the full effect of a will. Codicils were, in fact, useless unless there was a will prior or subsequent, which confirmed them either retrospectively or prospectively. (Gaius, ii. 270; 'Dig.,' 29, 7, 8.)

The subject of Roman wills is of great extent, and it involves questions of considerable difficulty. The principal authorities have been mentioned in this article, to which may be added Ulpian, 'Fragmenta,' tit. 20; 'Dig.,' 28, tit. 1, &c.; 29, tit. 1, &c.; 'Cod.,' 6, tit. 23.)

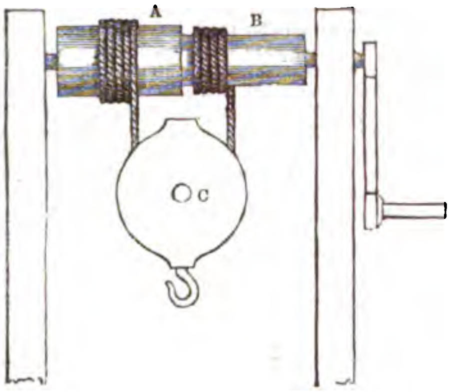
WILLOW, ECONOMICAL USES OF THE. The willow is applied to a very large number of useful purposes. The *white* willow, the *weeping* willow, and the *osier* willow, may be regarded as the types of three great classes, marking out three different kinds of applications. Taking them one with another, almost every part of the plant, in each of the three classes, is made available. The leaves of the growing tree furnish food for insects; the flowers for the honey-bee; the young leaves and shoots for cattle, horses, and goats. Sometimes they are dried and stored for this last-named purpose. In the north of Europe the inner bark is dried, ground, and mixed with oatmeal for peasants' food in years of scarcity. Willow twigs are much used in rude states of society for bridles, boat-cables, fishing-tackle, and various household implements. The bark of the young shoots is woven by the Russians for the upper parts of their shoes; while the outer bark serves for the soles. The outer bark as a material, and strips of the inner bark as a fastening, are much used for making baskets and boxes, and roofing houses. The bark, when steeped in water, may easily be stripped into fibres, and spun to make thread for cloth. The bark also yields a black dye, or tanning ingredient, and a medicinal agent. The wood of the willow is applied to many useful purposes. The timber of the larger trees is soft, smooth, and light. Its lightness led to its employment by the ancients in making shields. It has qualities which render it fitted to be used in making cutting boards for tailors and shoemakers; sharpening boards for fine steel instruments, such as cork-cutting knives; many kinds of turnery articles; shoemakers' lasts, &c. It is durable enough to form a good material for rafters in dry buildings, on account of its lightness. Its softness renders it applicable as a lining for waggons and carts intended to contain coal or stone, as it will not splinter from blows of hard angular materials. Being durable in water, it is much employed for water-wheels, floats of paddle-wheels, &c. Before the invention of iron hoops for cart-wheels, felloes were often made of red-willow wood, which speedily shod itself with small angular fragments of durable stone and gravel. The smaller portions of the wood of the trees are applied to an almost infinite variety of purposes. In some cases the straight stems of young trees, either split or whole; in some, the more vigorous shoots cut in two; and in some, the smaller shoots—are thus employed. Styles for ladders, fencing-poles, hop-poles, vine-props, clothes-props, rake-handles, handles of various tools and implements, hurdles, crates, hampers, hay and straw ricks, barrel hoops, binders for brocoli and other vegetables when sent to market, binders for standard trees and shrubs, skeleton frames for plants, are all made in large quantities from the parts of the willow now under notice. Many ornamental articles are made from strips or shavings of the wood of the white willow. Such shavings are first obtained in thin layers by a cutting instrument, and then separated into strips by a kind of steel comb having sharp teeth. The strips or ribbons are woven into a framework for bonnets and for light silk hats, and into a substitute for straw hats.

The downy substance which encloses the seed is in some countries used for wadding, and as a stuffing for cushions, beds, pillows, &c.

Some varieties of the tree are valuable when planted on the banks of rivers and canals, to retain the soil against the encroaching action of the water. Some kinds furnish good coppice, to be cut down every six or eight years for hoops, poles, and faggot-wood. The shrubby species make good hedges. The loppings, branches, and old trunks, when used as fuel, produce when dry a clear fire with little smoke. The wood produces excellent charcoal, especially for gunpowder.

Especially useful is one large group of willows, in furnishing the *osiers* for basket-making. The Dutch were the first to use osiers extensively for this purpose; the English imported the twigs from that country; but early in the present century, chiefly through the encouragement afforded by the Society of Arts, osier culture became extensive at home, and has ever since been continued. The osiers are cut in the form of rods. For coarse work they are used with the bark on; but for finer work the rods are peeled before being made up into bundles. For some work, again, the rods are used whole; while for others they are split or bisected. Some particular kinds only are known in the market as *osiers;* all the rest receive the general name of willows. For the mode of use, see Baskets.

WINCH AND AXLE is a machine constituting a small windlass, and consisting of a cylinder of wood which is capable of turning on its axis between two upright posts of the same material, or between the ends of a cast-iron frame: a lever at one or at each extremity of the cylinder, is attached to an iron axle passing through the latter at right angles to its direction, and is furnished with a handle, which is parallel to that axle. The name winch is given to a lever or handle of this kind, and the word is supposed to be derived from the verb *guincher*, signifying, in old French, to turn or bend in a curvilinear manner. The machine is used to raise a weight vertically, or to draw an object towards it; for which purposes the object is connected with it by a rope or chain which continually passes over the curve surface of the cylinder as the latter is made to turn on its axis by a man acting at the handle. Since the cylinder revolves once while the handle, or the extremity of the lever to which it is attached, is made to describe the circumference of a circle, it is evident that the mechanical power of the machine is precisely that of the wheel and axle. [Wheel and Axle.] When of a simple form it is employed to raise water from a well, and earth or some other material from the shaft of a small mine: and one of a complex nature is used, by means of a crane, to raise casks or heavy packages from the ground to the upper part of a building.



When great weights are to be raised, the machine is usually fixed in a frame of cast-iron, which is rectangular on the plan, but its extremities or faces have the form of a triangle, or of the letter A. The axle of the cylinder is supported on a horizontal bar at the middle of each end of the frame, and to the cylinder is attached a toothed-wheel which turns with it on the common axis: above this wheel and parallel to the cylinder is an iron axle which carries a pinion with teeth working in those of the wheel, and causing the latter to revolve, the pinion itself being turned by means of the lever and handle at one or at each extremity of the frame. A machine of this kind is called a *crab*; and when a weight is to be drawn horizontally, or raised above the cylinder, the machine must of course be bolted to the floor or firmly fixed in the ground, in order to prevent it from being moved from its place. In such machines there is generally, at one extremity of the cylinder a wheel, having on its circumference teeth like those of a saw; and a *click* or catch, which turns freely on a pin, is attached by that pin to the side of the frame in such a manner that it may fall between the teeth. By this contrivance, if the handle should break, or the moving power be taken off while the weight is suspended in the air, the latter is prevented from descending.

Machines of this kind are occasionally constructed which have the power of holding the weight in any part of its ascent or descent without a ratchet-wheel and catch. Such a machine consists of a barrel formed in two cylindrical portions, A and B, of different diameters, but having a common axle: the rope passes under a pulley in the block C, to which the weight is attached, and over the two cylinders, in such a manner that when the handle is turned it uncoils from the smaller and coils upon the larger portion. Thus every revolution of the barrel causes the larger cylinder to take up a quantity of rope equal in length to its circumference, while there is uncoiled from the smaller a quantity equal to the circumference of the latter: consequently, after each revolution, the quantity of rope between the axis of the cylinder and the pulley is diminished by the difference between the two circumferences, and the weight is raised up through a height equal to half that difference. Hence by mechanics, if $2R\pi$ represent the circumference of the circle described by the handle of the winch in one revolution, $(r'-r)\pi$ half the difference between the circumferences of the two cylinders, W the weight to be raised, and P the power applied to the handle, we shall have, in the state of equilibrium, $\frac{r'-r}{2R}W=P$.

The weight which may be balanced by a given power P will evidently be greater as $r'-r$, or the difference between the radii of the cylinder, is less; and the difference may be made very small without much increasing the friction. The only disadvantage attending the machine, when compared with an ordinary winch or capstan, is that it requires a much greater quantity of rope to raise or move the object through any given distance. It was first proposed in Europe by Mr. George Eckhardt, but machines of a like kind have, it is said, been long in use in the East.

The winch is employed with the common jack, which is used to lift great weights, or to move them through small distances. The handle turns a pinion with teeth, which act on others at the circumference of a small wheel; and on the axle of this is a pinion with teeth which work in those of a rack-rod. The axles of the wheel and pinions being let into the sides of a case of wood or iron, the revolution of the wheel produces a rectilinear motion of the rack; and one end of the case being fixed to the ground, or against an immoveable object, the extremity of the rack at the opposite end forces forward the body which is to be displaced. Sometimes, instead of a rack, the machine is furnished with a wheel whose axle is hollow, and cut in the form of a concave screw; within this screw is one of the convex kind, which by the revolution of the wheel and its axle is made to move in the direction of the latter, and thus to press before it the object which is to be removed. This machine has however considerable friction.

The force exerted by a man in turning a winch vertically varies according to the position of the lever with respect to the horizon. When the lever, or that part which is perpendicular to the axle, is perpendicular to the ground, and the handle is at the highest or lowest part of the circle described by the end of the lever, the man either pushes the handle directly from him, or pulls it directly towards him; and in each case he exerts a power which is estimated at 27 or 30 lbs.; but when the lever is in a horizontal position, the man either throws a great portion of his weight on the handle to press it down, or he exerts his muscular force in a direct manner to pull it upwards; and the force exerted in these positions is estimated at 140 or 160 lbs. The force exerted must evidently have different values between these quantities in other positions of the winch; and the practice is to cause two men to work at the same time to turn the machine, one being at each extremity of the axle of the cylinder. The levers of the two winches are placed at right angles to one another; consequently when one man is pushing or pulling horizontally, the other is pressing or pulling vertically, and thus the operation of turning goes on with nearly uniform intensity; the first man working in the least favourable position when the other is working in that which is most so. [Windlass.]

WIND is a motion of the atmosphere independent of that which it has in consequence of the diurnal and annual movements of the earth. The latter motion being performed in a part of space which may be considered as devoid of any resisting medium, the particles of air suffer no partial displacements on that account; and the friction of the particles against each other, and against the earth which they surround, must have long since brought the diurnal movements of the atmosphere and earth to a state of equality: thus, the angular velocity of the air on any parallel of terrestrial latitude being the same as that of an observer on the same parallel, the air would seem to be at rest about him. But if, from any disturbance of the equilibrium of the atmosphere, the particles should move less rapidly than the observer from west to east, or should acquire movements in some other direction, then the sensation of a wind would be experienced. The tides which take place in the atmosphere by the attractions of the sun, moon, and planets on the particles of air giving rise to differences in the heights of the vertical columns, they must necessarily cause inequalities of pressure in horizontal directions, and thus produce winds or currents of air; but it has been shown by La Place that these currents are scarcely sensible; and such attractions are by no means adequate to the production of the winds which are observed on the earth's surface. [Atmosphere, col. 692.]

The immediate effect of the solar radiation, communicating heat to any region of the earth's surface, is to generate an ascensional movement in the incumbent atmosphere, a bodily overflowing of its material above, and a relief of barometrical pressure below. The air of the cooler surrounding region, not being so relieved, will be driven in by the difference of hydrostatic—in this case of atmospheric—pressure, so arising, and thus originate two distinct winds: an upper one setting outward from the heated region; a lower inward, or towards it. "If the region heated be a limited one, these currents will radiate from and to it as a centre; if a linear belt, or a whole zone of the globe intervene, such as the generally heated intertropical region, they will assume the character of two sheets of air setting inwards on both sides below, uniting and flowing vertically upwards along the medial line, and again separating aloft and taking on a reversed movement."

These effects of heat upon the atmosphere, together with the rotatory motion of the earth, are the primary causes of all the phenomena of the winds, the latter having been found by modern meteorologists to have a much more extensive influence than was supposed when its part in the production of the trade-winds was first duly recognised. On this account, and because the consequences of these united actions impart to us a key to the whole subject,—including even that part of it which relates to revolving storms, or cyclones,—we shall now proceed to consider the trade-winds, both with respect to their theory and to their facts, in some adequate detail.

Trade-Winds is the term used by seamen to indicate the perpetual or constant winds, because they promote more than any other circumstance navigation and trade. These perpetual or trade-winds occur in all open seas on both sides of the equator, and to the distance of about 30 degrees north and south of it. They were not known to the ancients, and seem to have been unknown even to modern seamen up to the time of Columbus. Though before his time Portuguese navigators had proceeded as far as the Cape of Good Hope, they had not ventured to any great distance from the coast of Africa, and consequently they had not entered the regions where the trade-winds blow. Columbus, however, who had passed some time at the Canaries, to which the trade-winds extend in summer, seems to have conceived a just idea of their extent. On his first voyage, after leaving the Canaries, his crew were greatly alarmed at finding that the wind always blew from the north-east and east, and feared that they would be prevented by it from returning to their native country. Columbus did not participate in their fears; and on his return from the newly-discovered islands his track was north of the trade-winds, in the region of the variable winds. After the time of Columbus, European navigation extended rapidly in the Atlantic and Indian oceans, and the trade-winds became generally known. It does not, however, appear that any attempt to explain this phenomenon was made before the time of Galileo, who, in adopting the astronomical system of Copernicus and the revolution of the earth round its axis, thought he found some confirmation of this opinion in the trade-winds, which, as he conjectured, owed their origin to the revolution of the earth and to the circumstance that the atmosphere, though it participated in that motion, could not follow with equal speed the motion of the dense parts of our planet, and that a motion in the air was thus produced which was contrary to that of the earth round its axis, or from east to west. The strongest fact in favour of this hypothesis was the circumstance that the trade-winds occur only in the lower latitudes, where the surface of the earth, in its revolution round its axis, has to make a large circle in twenty-four hours, and consequently must move with a greater degree of rapidity than in the higher latitudes. Galileo's theory was relinquished about the end of the 17th century, in favour of a not less fallacious one proposed by Dr. Edmund Halley, who, however, had collected extensive information respecting these winds, and had indeed discovered several facts which were incompatible with the opinion of Galileo. The two most decisive were, that there are no trade-winds near the equator, where the diurnal motion of the earth is greatest, and that the trade-winds change their position according to the seasons, which could not take place if they were only the effect of the rotation of the earth. Galileo, however, appears to have had a true, though obscure, perception that the rotatory motion of the earth must be somehow concerned in the production of the trade-winds, though he singularly omitted to consider the operation of the sun's heat.

The trade-winds are met with on both sides of the equator. The mean boundary-line of the region in which they blow, and beyond which variable winds prevail, is about 28° lat. in the eastern parts of the ocean, but in the western parts this line is generally two or three degrees farther north and south. To the north of the equator they blow in the eastern parts of the ocean from the north-east, seldom from the eastward of east-north-east, or from the northward of north-north-east. In proceeding farther west they become more easterly, and often they blow from due east, and sometimes from the south of east, but generally they are one or two points north of east. To the south of the equator the trade-winds in the eastern parts of the ocean blow from south-east, and usually between south-east and east, but they also decline more to due east in reaching the western portion of the ocean. They do not occur ~~in~~ the vicinity of the continents, but are chiefly separated from them by a tract of sea in which either periodical or variable winds prevail. The trade-winds therefore are only experienced when we are well out from the land in the open sea. The wind blows with less force and steadiness in the eastern than in the western portion of the ocean. It is also stronger and more constant in the hemisphere where the sun is not, than in that which is exposed to its perpendicular rays; in the latter, however, it is more easterly than in the former. The region in which the trade-winds occur is distinguished by an almost continual serenity and fair weather. Though the trade-winds of the northern and southern hemisphere blow in an oblique direction towards one another, they do not meet in general, but are divided by a tract of sea in which calms frequently prevail, and also variable light winds, mostly from the west, are met with. This region of the calms is distinguished by a thick foggy air, and frequent rains of short duration attended by thunder and lightning. The region of calms which separates the north-east trade-winds from the south-eastern, and which usually occupies a width of four or five degrees of latitude, is not always found at the same part of the ocean, but advances farther north when the sun has a northern declination, and farther south when it is in the southern hemisphere. [CALMS.] The same is observed respecting the winds themselves. Though the mean boundary-line of the trade-winds is 28° of lat. in the eastern parts of the ocean, it extends two, three, and even four degrees farther north when the sun approaches the northern tropic, and about the same distance farther southward when the sun is near its greatest southern declination. It sometimes happens that a north-eastern wind occurs as far north as 40° in the Atlantic, along the southern coasts of Spain and Portugal, but as this is seldom the case, it is supposed that such a wind cannot be considered as a trade-wind, but only as one of the variable winds which prevail to the north and south of the trade-winds. There are also a few instances on record in which the north-east and south-east trade-winds have not been found separated by a region of calms, but in which a vessel, with the intervention of a calm of short duration, has passed from one trade-wind into the other.

The true explanation of these "magnificent phenomena," as they have justly been called, according to Dove and Herschel, was first delivered in the 'Philosophical Transactions' for 1735, by George Hadley. It has often been erroneously attributed to Dr. Edmund Halley, in part, doubtless, from the similarity of his name, and partly on account of a theory of these winds, now long proved to be fallacious, having been actually proposed by him, as already noticed. The true theory was also divined by the sagacity of John Dalton, who, not knowing what Hadley had done, printed it in his 'Meteorological Observations and Essays' in the year 1793, but discovered Hadley's priority in time to acknowledge it in his preface.

The astronomical point of view from which the objects of meteorology have always been viewed by Sir John F. W. Herschel, has given to his treatment of atmospheric phenomena, a breadth and perspicuity scarcely to be found in the writings of other meteorologists. His view of the theory of the trade-winds presents a remarkable example of this, and, as a whole, is, we think, unequalled. In what follows we give an epitome of it, condensed from two works—his 'Outlines of Astronomy,' and 'Treatise on Meteorology,' with some adaptations of our own.

It is a matter of observed fact that the sun is constantly vertical over some one or other part of the earth between the tropics, and that the whole of the zone or belt so included between the tropics, and equally divided by the equator, is, in consequence of the great altitude attained by the sun in its diurnal course, maintained at a much higher temperature than those regions to the north and south which lie nearer the poles. The heat thus acquired by the earth's surface, agreeably to the principles explained above, is communicated to the incumbent air, and becomes the universal primary cause of the phenomena of the winds, in conjunction with the earth's rotation. The colder and heavier air glides in on both sides, along the surface, from the regions beyond the tropics; while the displaced air, thus raised above its due level, and unsustained by any lateral pressure, flows over, as it were, and forms an upper current in the contrary direction, or towards the poles; which being cooled in its course, and also pressed down by the mass of the atmosphere above to supply the deficiency in the extra-tropical regions, thus keeps up a continual circulation. "That this is a real cause (*vera causa*) is placed in complete evidence by the general fact that the atmospheric pressure at the surface of the sea diminishes regularly from either tropic to the equator, where the barometer stands habitually about 0·2 in. lower than in the temperate zones."

The principle whose action was made known and applied by Hadley now comes into play. The equatorial portion of the earth's surface has the greatest velocity of rotation, and all other parts less in the proportion of the radii of the circles of latitude to which they correspond. But as the air, when relatively and apparently at rest on any part of the earth's surface, is only so, because in reality it participates in the motion of rotation proper to that part, as indicated at the beginning of this article, it follows that when a mass of air near the poles is transferred to the region near the equator by any impulse urging it directly towards that circle, in every point of its progress towards its new situation it must be found deficient in rotatory velocity, and therefore unable to keep up with the speed of the new surface over which it is brought. Hence, the currents of air which set in towards the equator from the north and south, must, as they glide along the surface, at the same time lag, or hang back, and *drag upon* it in the direction opposite to the earth's rotation, that is, from east to west. Thus these currents, which but for the rotation would be simply northerly and southerly winds, acquire, from this cause, a *relative* direction towards the west, and assume the character of permanent north-easterly and south-easterly winds.

It follows from this, then, that as the winds from both sides approach the equator, their easterly tendency must diminish; a fact which though inevitably resulting from the principle maintained by Hadley, was reserved for the late Captain Basil Hall to reason out, and, though thus for the first time, in a very distinct manner, in his 'Fragments of Voyages and Travels.' The lengths of the diurnal circles increase very slowly in the immediate vicinity of the equator, and for several degrees on either side of it hardly change at all. Thus the friction of the surface has more time to act in accelerating the velocity of the air, bringing it towards a state of *relative* rest, and diminishing thereby the relative set of the currents from east to west, which, on the other hand, is feebly, and, at length, not at all, reinforced by the cause which originally produced it. Arrived, then, at the equator, the trade winds must be expected to lose their easterly character altogether. And not only this, but the northern and southern currents here meeting and opposing, will mutually destroy each other, leaving only such preponderancy as may be due to a difference of local causes acting in the two hemispheres—which in some regions around the equator may lie one way, in some another—as will presently be seen. "The result, then," says Sir John Herschel, "must be the production of two great tropical belts, in the northern of which a constant north-easterly, and in the southern a south-easterly, wind must prevail, while the winds in the equatorial belt, which separates the two former, should be comparatively calm, and free from any steady prevalence of easterly character. All these consequences are agreeable to observed fact, and the system of aërial currents above described constitutes in reality what is understood by the regular *trade winds*."

On the subject of the region of calms, intervening between the trade-winds, Kämtz, in his 'Manual of Meteorology,' remarks, "In the space between the two trade-winds the air is heated to the highest degree. There the ascending currents of air are the most rapid; and by this quick ascent the velocity of the wind blowing along the surface of the sea is greatly diminished. Besides it would seem that the upper and lower current of the air come into contact with one another at a comparatively small elevation above the surface of the globe. These two circumstances appear to be the reason why no regular winds are met with within the region of the calms."

We now proceed to review the actual and local phenomena of these winds. Two currents of air are found within their limits, of which the lower runs to the south-west, north of the equator, and to the north-west, south of it, and the upper in the opposite direction. In this manner a kind of atmospherical circulation is formed, which is admirably adapted for the preservation of animal life. The existence of this counter-current of air in the upper regions had only been inferred from the theory, and nothing could be adduced to prove it, except that within the trade-winds the clouds, which rarely make their appearance in this region, generally take a direction which corresponds to that of the supposed current of air. But in 1812 an event took place which was rather more decisive in favour of the theory. In the eruption of the volcano of St. Vincent, considerable quantities of ashes and other volcanic matter descended on and spread over the island of Barbadoes. This event certainly excited a high degree of surprise, as in this part of the Caribbean Sea the trade-wind always blows with a considerable force, so that vessels sailing from St. Vincent to Barbadoes are obliged to make a circuitous course of some hundred miles to reach the place of their destination. It can hardly be questioned that the volcanic matter was raised, by the eruption of the volcano, to such an elevation that it reached the counter-current, which, blowing from the west, carried it to Barbadoes. Humboldt adduces also, in support of the theory, the strong south-western wind which he experienced at the top of the Peak of Teneriffe, whilst all the other parts of the islands were under the sway of the trade-wind; and this observation is also confirmed by Glass, who, in his 'History of the Canary Islands,' states that during the trade-winds the most elevated parts of those islands experience a continual westerly wind, which blows with considerable force. Confirmatory facts on this point, as observed by Professor C. Piazzi Smyth, will be found at the end of the article CLOUD. Lastly, we may adduce, in corroboration of the theory, the instantaneous change of wind which is frequently experienced when the limits of the trade-winds are passed.

It has been already observed that the boundary of the trade-winds towards the nearest pole does not always occur in the same part of the ocean, but changes with the seasons. The difference is considerable. At the greatest southern declination of the sun, in December and January, the northern boundary of the north-east trade-wind of the Atlantic occurs to the south of 25° N. lat., whilst in the opposite season, from June to September, it occurs about 32° N. lat. Thus we find a tract of sea, seven degrees of latitude in width, which is alternately exposed to the sway of the trade-winds and of variable winds, and nearly in the middle of this tract the Canaries are situated. These islands, therefore, are within the trade-winds for six months, and for the remainder of the year without them. Von Buch, in his description of these islands, has given an account of the regular manner in which the trade-wind advances towards the north, with the progress of the sun in the northern hemisphere, and in which it recedes when the sun passes the equator on his return to the southern hemisphere, observing that the south-western wind, which is always found in the upper regions of the atmosphere above the trade-winds, does not make its appearance on the south, as may be inferred from the direction in which it blows, but is first experienced at Madeira, whence it gradually advances to Teneriffe and the other Canaries. Whilst this south-western wind advances from north to south, it also descends by degrees from the upper to the lower regions, and to the surface of the globe. On Teneriffe this takes place in October, when the south-west wind is experienced on all mountains 6000 feet high, but generally one week passes, and sometimes several weeks, before the south-western wind sinks to the level of the sea.

The trade-winds are only met with on the sea; but in some countries of the globe between the tropics, or near them, regular and constant easterly winds occur, which may owe their origin to the same cause. These winds only occur in extensive level plains, where there is nothing to break their force or to change their direction; for if the wind comes in contact with high land or mountains, its regular progress is obstructed. But over a considerable tract of low level land the wind passes without being much changed in its direction and velocity, particularly if the land be barren and destitute of moisture. In the Sahel, or western part of the Sahara, an easterly wind blows all the year round with great force, but in the eastern district of the Great Desert it is less constant and less violent, so that in all respects it may be compared with a trade-wind. An easterly wind is also always found on the plain drained by the Amazonas; and by its assistance the voyage against the strong current of the river may be accomplished nearly in the same time as the voyage downwards by means of the current. Humboldt found that this easterly wind, which, near the mouth of the Amazonas is moderate, has acquired such a force at the base of the Andes, that it is almost impossible to keep one's footing against it. A similar easterly wind, though of less strength, is found in the great plain which is traversed by the lower course of the Orinoco.

The countries just mentioned, in which these easterly winds blow constantly, are contiguous to those parts of the Atlantic Ocean where trade-winds in general are regular all the year round. But the trade-winds of the ocean and the land-winds of the plains do not come into contact with one another. They are separated by a tract of the globe in which other winds prevail. This tract lies within the ocean, and extends along the coasts of the continents; its width varies greatly. Where it lies east of the trade-wind it is usually a hundred miles wide, but it is of inconsiderable breadth when the land lies to the west of the trade-winds. The continuity of the easterly winds is evidently interrupted by the difference of the temperature of the air incumbent on the sea and on the land. This difference changes with the seasons, the air over the land being hotter than that of the sea when the sun is near, and colder when it is far off. Hence it follows that during the first period the wind blows from the sea to the land, and in the second from the land to the sea. Thus a kind of monsoon is produced along the coasts of the continents, even within the region of the trade-winds. A large island in such a situation is therefore surrounded by winds blowing from all quarters. When the land of Australia is heated by the presence of the sun in the southern hemisphere, the wind generally blows from the westward upon the north-western coast, and from the south-west upon the western coast; from the south-west, south, and south-east on the southern coast; and from the south-east and east upon the east coast. In the opposite season, however, the winds are less regular, because the greatest part of the island is then without the reach of the trade-winds.

The trade-winds occur on both sides of the equator in the Atlantic and Pacific oceans, but they vary considerably in extent and force in both oceans. Some account of this difference is given under the heads of ATLANTIC OCEAN and PACIFIC OCEAN, in GEOG. DIV. We shall here add, respecting the last-mentioned sea, that the trade-winds in the southern parts appear to be subject to great changes in direction and force, and that they properly occur only along the coasts of South America, where a constant south-easterly wind is met with at the distance of 500 to 600 miles from the coast: but in the middle of the Southern Pacific the trade-wind seems by no means regular and constant. Admiral Fitzroy, in speaking of the Paamuto Islands, or the Dangerous Archipelago of the Low Islands, says that among them a steady south-easterly trade-wind prevails from March to October, but that in the rainy season, from October to March, westerly winds, squalls, and rains are frequent; and in the abstract of his meteorological journal we find that in running from the Galapagos to Otaheite he experienced only south-eastern winds near the equator; and that in the remainder of his voyage the wind blew almost constantly from the north-east, north-north-east, or north-east by east. Kotzebue, on his first voyage, observed it as a remarkable circumstance, that between Easter Island and 14° 51′ S. lat. he met only with winds blowing from north, north-east, and east-north-east. This anomaly in the trade-winds of the Southern Pacific is probably produced by the innumerable islands and coral rocks which cover that ocean between the equator and the southern tropic, and extend from 130° W. long. to the coast of Australia. Horsburgh says, probably from his own observation, that "where shoal coral-banks shoot up out of the deep water in many places between the tropics, a decrease of the prevailing wind is frequently experienced; for when a steady wind is blowing over the surface of the deep water, no sooner does a ship get upon the verge of a shoal coral-bank than a sudden decrease of the wind is often perceived. This is, in his opinion, occasioned by the atmosphere over these banks being less rarefied by the increased evaporation than that over the deep water, and consequently not requiring so great a supply of air to restore the equilibrium as the circumjacent parts, which are more rarefied and heated." When such effects, according to the statement of this intelligent hydrographer, are produced by single coral-banks in the midst of the ocean, we may easily comprehend that their number and immense extent in the Southern Pacific not only diminish their force, but change the direction of the trade-winds, and that these reefs and islands affect them nearly to the same extent as a large continent. It appears that in the Southern Pacific the trade-winds are replaced by the north-eastern, northern, and western winds only during the period when the sun is in the southern hemisphere. A south-eastern trade-wind prevails also in the Indian Ocean from within a few degrees of the eastern side of Madagascar nearly to the coasts of Australia, between the parallels of 10° and 28° S. lat.; but in this ocean from 10° S. lat. to the coasts of Hindostan the winds are periodical; the influence of the land issuing in a complete reversal of the north-east trade during a considerable portion of the year, and the production of MONSOONS, that is of winds which blow half the year in one, and the other half in the contrary direction, as explained at length in the article devoted to them.

Even very limited local movements of the atmosphere are modified by the same cause. It is a remark as old as Bacon, and afterwards confirmed by Mariotte in France, Sturm in Germany, and Toaldo in Italy, and since by "many other writers both in Europe and North America, that the wind has a decidedly preponderating tendency to veer round the compass according to the sun's motion, that is, to pass from north through north-east, east, south-east, to south, and so on round in the same direction through west to north; that it often makes a complete circuit in that direction, or more than one in succession (occupying sometimes many days in so doing); but that it rarely veers, and very rarely or never makes a complete circuit, in the contrary direction." According to Sir John Herschel, Professor Dove was the first to show that this tendency is a direct consequence of the rotatory motion of the earth; it has therefore been denominated "Dove's law of rotation of the wind," to which we shall shortly return.

The heated equatorial air, while it rises and flows over towards the poles, carries with it the rotatory velocity due to its equatorial situation into a higher latitude, where the earth's surface has less motion. Hence, as it travels northward or southward, it will *gain* continually more and more on the surface of the earth in its diurnal motion, and assume constantly more and more a *westerly* relative direction; and when at length it returns to the surface, in its circulation, which it must do more or less in all the interval between the tropics and the poles, it will act on it by its friction as a powerful south-west wind in the northern hemisphere, and a north-west in the southern, and restore to it the impulse taken up from it at the equator. "We have here the origin of the south-west and westerly gales so prevalent in our latitudes, and of the almost universal westerly winds in the North Atlantic, which are, in fact, nothing else than a part of the general system of the re-action of the trades, and of the process by which the equilibrium of the earth's motion is maintained under their action." The only winds of a regular character which remain to be noticed are the land and sea breezes which occur diurnally on the coasts and in the islands of the tropical regions, and the periodical winds which are observed to prevail in some parts of Europe. The first are probably caused by the inequality of the sun's action on the land and water; and both, by the tendency of the atmosphere to preserve a state of nearly uniform density. During the day the land acquires a temperature higher than that of the neighbouring ocean: the atmosphere above it consequently becomes rarefied, and from about 9 A.M. the air from the sea flows towards the land, to occupy the partial vacuum there produced. In proportion as the heat of the land goes on increasing, the force of the sea-breeze also increases, and this continues till 2 or 3 P.M. After that time the temperature over the land diminishes more rapidly than over the sea, as the heat more readily escapes by radiation from the land than from the water, and about sunset the breeze from the sea ceases. During the night, the land continuing to cool, the air over the sea becomes comparatively warmer and more rarefied, and a breeze from the land takes place: this wind augments in force till near sunrise, when the temperature of the earth begins to increase, and about 9 A.M. the wind blows from the sea as at first. These land-breezes diverge in every direction towards the coasts of the tropical islands from the high lands in their interior. Mr. Redfield modifies the hypothesis above stated by assuming that when the stratum of air lying on the surface of land which ascends towards the interior of a country becomes rarefied by the sun's heat, it is forced by an excess of pressure at its lowest part to move up the slope; and during the night the stratum of air on this inclining surface acquiring greater density, its gravity causes it to descend towards the sea. ('Amer. Journal of Science,' vol. xxxiii., No. 1.)

The Etesian winds (so called from ἐτησίαι, "annual") is a designation formerly given only to those which every summer blow during six weeks over the countries bordering the Mediterranean; but it has since been applied to other periodical winds, as those which blow on the coast of Holland. They commence in the Levant about the middle of July, rising at 9 A.M., and continuing during the day-time only: the direction of the current of air is from north-east to south-west; and it is probably caused by the rarefaction of the atmosphere nearly under the tropic of Cancer, in consequence of the heat of the sun at that season. Pliny states that, in Spain and Asia, the etesian winds blow from the east; and he adds that they also take place in winter, when they are called Ornithian winds: these are, however, said to be more gentle than the others, and to continue during nine days only. (Smyth's 'Mediterranean,' p. 270.)

It may be observed, in addition to what has been said respecting the trade and other regular winds, that those which prevail in the temperate zones are probably the results of currents proceeding about the earth from the tropical regions. Professor Dove suggests (in a paper published in Poggendorff's 'Annalen,' of which a translation appeared in the 'Philosophical Magazine' for September, 1837) that when the sun is on the meridian of any place, as London, situated beyond those regions, the currents of heated air which proceed from the point vertically under him must arrive at that place from the south earlier than at any other place eastward or westward of it on the same parallel of latitude. But in proportion as the sun becomes successively vertical at different points westward of the meridian of London, the currents of air, in describing great circles of the sphere, arrive later, and in a direction from the westward of south; and when, during the summer, he is vertically over a point about 60 degrees west of London (that is, in the evening), they arrive nearly from the west. At midnight, when the sun is on the meridian under the horizon, the current of air passing over the north pole is felt as a north wind; and after this time the currents coming from points having less than 180 degrees of longitude eastward are felt as easterly winds, which become due east in the morning when the sun is about 60 degrees eastward of the meridian. In this order the movements take place daily, except when the currents are disturbed by accidental circumstances or by the influence of currents which proceed from the pole to the equator in order to supply the place of the heated air which ascends from the surface of the earth between the tropics.

The sun is not the sole cause of the currents which are observed in the atmosphere, for they often arise from the condensation of the aqueous vapours which are constantly rising from the surfaces of seas and rivers. Such vapours, being lighter than air, ascend in the atmosphere, carrying with them a quantity of heat, which escapes on arriving in a region where there is less heat than at the surface of the earth; and the vapour being then reduced to a state of water, a partial vacuum is produced, into which the neighbouring air rushes. The heat is at the same time conveyed by the wind with the drops of water, and thus the region in which the rain is falling is sometimes warmer than those which surround it. Rain-winds are produced by the air which descends to the ground with the globules of water; the particles of air being disengaged from the globules on the latter striking the ground, are then driven off, with considerable force, in every direction from the place where the rain is falling.

All mountain districts are subject to sudden and violent gusts of wind from the interruptions which the ridges of high land create to the general currents of the air; but that which is called the Helm-wind, at Crossfell, in Cumberland, is one of the most remarkable of these phenomena. It occurs at uncertain times between the end of September and the month of May, and occasionally, though rarely, in summer. It is stated that, when not a breath of wind is stirring, and scarcely a cloud is to be seen, there is suddenly formed a line of clouds, called the "Helm," extending nearly north and south along the top ridge of the mountains; and nearly parallel to this, another line of clouds, called the "Bar," forms itself: the first of these lines of clouds is well defined at its western and the other at its eastern edge; and the lines unite together at their northern and southern extremities so as to contain between them an elliptical space whose length, in the north and south direction, varies from 8 to 30 miles, and its breadth, in an east and west direction, from half a mile to 4 or 5 miles; the highest point of the ridge of mountains being about the middle of the first line of clouds. In a few minutes after the formation of the Helm a violent wind begins, within the space between the clouds, to blow from some eastern point of the compass, but generally from due east to due west: its force is such as to break trees, disperse the grain in stacks, and overturn a cart with its horse. It continues frequently for nine successive days, and its noise is said to resemble that of the sea in a violent storm; but it is seldom accompanied by rain. No satisfactory hypothesis has yet been offered to account for the phenomenon; but that which seems most probable is, that the air from the coast of Northumberland, being cooled as it rises to the summit of the mountain, and there condensed, descends from thence with great force, by its gravity, into the district at the foot of the western escarpment. (Rev. J. Watson, in the 'Reports of the British Association,' vol. vii.)

If we contemplate the influence of the winds in the economy of human life, we shall find them highly beneficial. Though storms are often destructive to life and property, both at sea and land, yet they contribute greatly to preserve the health of animated beings by the dissipation of noxious exhalations: the winds impel the clouds from place to place, and thus diffuse over great tracts of country the rains which contribute so much to fertilise the ground. Wind is extensively employed in giving motion to machinery; and, till the recent application of steam, it was the only power by which ships were transported across the ocean between different regions of the earth.

Whirlwind is a violent movement of the atmosphere in a circular or spiral direction apparently about a mathematical axis, the latter having at the same time a progressive motion, rectilinear or curvilinear, on the surface of the land or sea.

The tornados of North America and the coasts of Africa, as well as the typhoons in the sea of China, have long been known as violent tempests in which the wind has a revolving motion of this kind, but these terms are commonly applied to such storms as are of short duration and comparatively of small extent, the diameters of the vortices varying from a few hundred yards to one or two miles. It is now ascertained, by such evidence as leaves scarcely any doubt of the fact, that in all or most of the great storms which agitate the atmosphere the wind has a rotatory movement, and that the diameter of the circle within which the gyration is performed is sometimes equal in extent to several hundred miles: in great whirlwinds the axis appears to be either vertical or nearly so, but in those of small extent its inclination is often inconsiderable, and it is sometimes parallel to the horizon.

As early as the middle of the 17th century the revolving motion of the wind, during the great hurricanes which take place in the West Indies, appears to have been noticed; and in a description of them, which was given at that time in the 'Philosophical Transactions,' it is stated that, after a cessation of the trade-winds, the storm begins from the north; that the wind afterwards goes round to the north-west and then to the south, the storm subsiding when the wind comes to the south-east: and in Colonel Capper's work on the 'Winds and Monsoons,' which was published in 1801, the gyratory nature of the storms in the East Indian seas is inferred from the recorded changes in the directions of the wind during the storms of 1760 and 1770. Whirlwind storms appear however to have been then considered as local and temporary; and we owe to the late Mr. Redfield, of New York, the discovery that they have a progressive as well as a revolving motion. Dr. Franklin ascertained that the storm which he witnessed at Philadelphia in 1748, took a certain time to arrive at Boston, but he did not pursue the subject, and, from a mistaken estimate of the distance between those cities, his opinion of the rate of movement is now known to be erroneous.

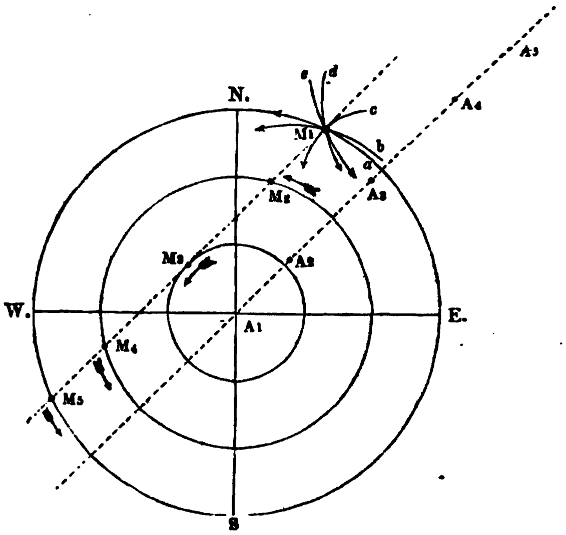
Currents of air are frequently, as at the changes of the monsoons in the East Indian seas, impelled obliquely against each other, and thus rotatory motions in the atmosphere may be produced, exactly as eddies or whirlpools are formed in currents of water. [WHIRLPOOL.]

Mr. Redfield, in his 'Observations on Storms,' in the 'Transactions of the American Philosophical Society,' 1841, offers an opinion that generally during a gale there is, in the lower part of the atmosphere, a spiral motion inclining downwards and towards the centre; and in the higher regions a like spiral motion inclining upwards and towards the exterior. He adds that, in storms of great extent, there is sometimes found a considerable area within which the winds are moderate and blow in various directions. These characters of a revolving storm appear to be verified by the manner in which trees were prostrated during the hurricane which occurred in New Brunswick in June, 1835; when, about the centre, bodies of great weight were carried spirally upwards, and, on opposite sides of the storm's path, the trees were thrown in contrary directions. It is observed that when a storm rages violently, the doors and windows of houses are often forced outwards, either from the centrifugal force caused by the revolving motion, or from the expansion of the air within, when a temporary rarefaction takes place on the exterior; and from the movements of the clouds it appears often that a storm, in passing over a place, is in activity at a considerable altitude before it descends to the earth's surface.

That a whirlwind may have a progressive as well as a revolving motion may be easily understood if it be observed that, as the atmosphere in the tropical regions moves from east to west with respect to the surface of the land or sea, it may, after crossing the Atlantic and Pacific oceans, be arrested in its progress westward by the continents of America and Asia, and deflected from thence towards the poles: the whirlwinds formed by electricity or otherwise in the general current of air will consequently be carried with the deflected branches into high northern and southern latitudes; and it may occasionally happen that, from the nature of the deflecting forces, the path of the axis of a revolving storm in either branch is a curve line like a segment of a circle or a parabola. Sir John F. W. Herschel, at the meeting of the British Association in 1838, suggested that the Gulf-Stream may be the cause of the nearly parabolic curves assumed by the paths of the storms on the coast of North America: the paths nearly coincide with the course of this stream; and the warmth of the water, by increasing the temperature of the air above it, must disturb the equilibrium of the atmosphere, and maintain the storms which had their origin in a lower latitude.

It is evident that the velocity of the wind in a revolving storm must be the greatest and the least respectively on opposite sides of the axis of rotation, in a diameter which is perpendicular to the path of that axis; for on one side the direction of the revolving current conspires with that of the progressive motion of the storm, and on the other it is contrary to it. In other parts within the limits of the storm the direction and velocity of the wind must be compounded of the rotative and progressive motions; and it will happen frequently that a temporary calm is experienced at each point on the earth's surface at which the axis of the storm successively arrives.

The phenomena of tropical storms are not precisely such as they would be if the air had a simple movement of rotation; the particles of air, while revolving, are probably subject to undulatory motions in spiral curves, and the wind appears sometimes to shift to different points all round the compass. Mr. Redfield states that, in small whirlwinds, the axis of rotation appears at times to describe gyrations in looped curves about its mean place in the line of progressive motion; and the like gyrations probably take place in those of an extensive kind; indeed in some voyages under the influence of revolving storms they have been actually observed: but in order to simplify the explanation of the phenomena of whirlwinds, it is usual to assume that the particles of air revolve in the circumferences of circles whose centres are in the axis; the latter having at the same time a movement of progression in a rectilinear or curvilinear direction. Now, if the plane of the paper represent the surface of the sea, and a line through A_1, perpendicular to it, represent the axis of a whirlwind whose north and south diameter is N., S., and in which the particles of air are supposed to revolve (for example) in the direction indicated by the order of the letters N., W., S., E.; the progressive movement of the axis being also supposed to be from A_1 through N., or from south to north: then, since at N. a tangent to the circle lies due east and west, it is evident that a ship at that point would experience a wind blowing from the east when the centre of the storm is at A_1; and if the ship remain stationary, the wind will continue to blow from the same quarter till A_1 arrives at N., the tangents to the concentric circles supposed to be described by the particles being due east and west at the northern points of the circumferences as they successively arrive at N., and the wind in all the northern half of the storm revolving in the direction E., N., W.: but after this time, the wind blowing in the direction W., S., E., must be felt at N. as a west wind till the remaining half of the storm has passed over that point. In like manner, if the axis of the storm were to move from A_1 towards W., a ship supposed to be stationary at the latter point would feel the gale from the north till A_1 arrives at W.; after which, as the eastern semicircle passes over that point, the ship would experience a wind from the south.



Again, if the axis were to move from A_1 towards A_5, that is, from south-west to north-east, for example, the direction of the whirlwind being, as before, according to the order of the letters N., W., S., E., and the ship being supposed to remain stationary at some point, as M, till the storm has passed over it, then the line of direction in which the points of the whirlwind successively overtake the ship being M_1 M_5, parallel to A_1 A_5, the arcs $a M_1$, $b M_1$, &c., will represent the several directions in which the wind will successively be felt at the ship during the continuance of the storm. Thus, the axis of the whirlwind being at A_1, the convex surface of the storm has just reached the ship, and the wind blows in the direction $a M_1$, or in the circumference of the circle whose centre is A_1, that is, nearly from the east-south-east; next, the axis being at A_2, the point M_2 in the circumference of the circle whose radius is A_1 M_2, is at M_1; and then, at the ship the wind is felt in the direction $b M_1$, or in the circumfereuce whose radius is A_2 M_1, or its equal A_1 M_2, that is, nearly from the east-by-south. Again, the axis being at A_3, the point M_3 in the circumference whose radius is A_1 M_3, is at M_1; and then at the ship the wind is felt in the direction $c M_1$, or in the circumference whose radius is A_3 M_1, or its equal $A_1 M_3$, that is, from the north-east. When the axis is at A_4 and A_5 the points M_4 and M_5 arrive at M_1, and the wind there is felt successively in the directions $d M_1$ and $e M_1$, that is, nearly from the north-by-west, and from the north-north-west. When the axis has advanced beyond A_5, it is evident that the whirlwind ceases to have any effect on a ship at M_1. If tangents were drawn at M_1 to the arcs $b M_1$, $c M_1$, &c., they would evidently be parallel to tangents at the corresponding points M_2, M_3, &c.; therefore the directions in which the circumference of the concentric circles meet the line of direction M_1 M_5 will be those in which the wind is felt at the ship during the storm. In like manner, the successive directions in which the wind blows in a revolving storm may be exhibited, whatever be the situation of the ship and the movement of the axis of rotation.

The diagram, therefore, may be regarded as a plan or a horizontal section, or, more accurately, a section at right angles to the axis, of a revolving storm. In the sequel of this article another diagram will be found, presenting vertical sections of such storms, or sections parallel to their axis, and at right angles to their greatest diameter.

The hurricanes or whirlwinds of the Atlantic commence in a part of the ocean which is frequently designated the region of variable winds, and is situated between 10° and 20° N. lat., and between 55° and 60° W. long., and their progress along the coast of the United States is marked by the devastation they so often produce. They are felt between July and October, but they are most frequent and violent in August and September; and being on the great line of communication between Europe and the West, the phenomena which they present have been more attentively observed than those of the storms in any other region of the earth. The valuable publications of Mr. Redfield contain nearly all the details which have yet been collected concerning them; while the works of the late Sir W. Reid [Reid, Sir William, in Biog. Div.], especially that entitled 'An Attempt to develope the Law of Storms,' contain almost all that is known of the whirlwinds in the southern hemisphere.

In the 'American Journal of Science,' vol. xx., it is shown that the storm which took place in September, 1821, began in the West Indies, and arrived off the coast of the United States, in lat. 35° N., at daylight, September 3rd, when the wind blew from E.S.E. On the same day, at 11 A.M., the storm commenced at Cape Henlopen, with the wind in the same quarter, but it afterwards shifted to E.N.E., and blew during nearly an hour: a calm of half an hour succeeded, when the wind shifted to W.N.W., and blew with great violence. At New York the storm commenced at 5 P.M., from E. and N.E., the wind blowing with fury for three hours, and then it changed to W. At Boston the hurricane commenced at 10 P.M., but beyond this city it was not traced. All the phenomena just mentioned indicate, agreeably to the principles above explained, a revolving hurricane in which the direction of the rotation was according to the order of the cardinal points, N., W., S., E., while the progressive movement of the axis was about N. by E. The temporary calm at Cape Henlopen seems to show that the centre of the vortex was then near that place.

In the same work it is stated that, during the hurricane of 1830, at the Bahama Islands, the wind veered almost round the compass in the night of August 14. The storm appears to have passed from the island of St. Thomas, near Porto Rico, to the south-east coast of Nova Scotia, in about six days, consequently it must have moved at the rate of about 17 miles per hour; and by the positions of the different points at which its effects were at the same time felt, its diameter must have been about 150 or 200 miles.

A movement of progression combined with a movement of rotation in the direction of the points N., W., S., E., is also indicated by the phenomena of the Barbadoes hurricane in August, 1831, in July, 1837, and of the hurricane at Antigua, August 2 of the latter year. But of the North Atlantic storms, that which presents the most remarkable phenomena is one which raged between the 12th and 23rd of August, 1837. Details of the circumstances attending it have been given at length, with a chart of its course, by Sir W. Reid, in his work on storms; and it appears that it was first felt in lat. 17° 30′ N., about 400 miles eastward of Antigua, though it may have had its origin still farther eastward.

By the effects experienced at different points on the ocean, Sir W. Reid concludes that the centre or axis of the storm advanced at first from east to west nearly; and after moving in that direction about two days, it turned towards the north-west, as if the storm had been abruptly deflected from the land; and when the whirlwind ceased to be noticed, it was passing eastward across the Atlantic to the south of Newfoundland. On the 18th of August, 1837, a ship, named the Rawlins, was becalmed for an hour in lat. 30° 30′ N. nearly; at that time another, named the Calypso, above three degrees northward of the Rawlins, was thrown on her beam-ends with the wind successively at N.W., W., and S.W.; and a ship, named the Sophia, situated about as far towards the north-east of the Rawlins, evidently eastward of the storm's centre, experienced the hurricane from the E.N.E., E., and E.S.E. Previously to the temporary calm, the wind at the place of the Rawlins had been N.E. by E. and N., and afterwards it suddenly changed to the S.W. These circumstances sufficiently indicate that the whirlwind had then a progressive motion towards the north-west, and at the same time a rotation in the direction of the points N., W., S., E. On the 20th of August the wind at the point occupied by the Sophia appeared to veer back, first to the east, and subsequently to the north; and since at this time the progressive movement of the hurricane had changed from a south-west to a north-east direction, the veering of the wind admits of being explained on the supposition that the Sophia had then fallen into the western semicircle of the whirlwind, while the latter, still revolving in the same direction, passed over her.

That independent whirlwinds occasionally interfere with each other may be inferred from the circumstances attending the voyage of the Castries from St. Lucia to England in the same year (1837). This ship, between the 14th and 25th of August, sailed nearly from south to north on the chord of the arc described by the centre of the great hurricane just mentioned. On the 14th and 15th, in about the 18th degree of north latitude, where the wind usually blows from the east, she felt a gale, which at first came from S.S.W., and afterwards changed to S.E., as if she had crossed the eastern side of a storm revolving in the direction N., W., S., E., and whose centre was moving nearly from east to west: this was in fact the said hurricane near the place where it was first observed. The Castries then sailed northward with fair weather till August 24th, when, in lat. 35° 46′ N. and in long. 57° 40′ W. nearly, she was overtaken by a whirlwind which passed over her. Now this could not have been the great hurricane before mentioned, since at that time the latter had passed beyond the spot towards the N.E., and the rotation at its southern extremity must have caused at the place a west wind to be felt; whereas the direction of the wind at the ship was at first from E.S.E., subsequently changing to N.E., N., and N.W.: the ship must evidently therefore have been then in the north-eastern side of a whirlwind coming up from the S.E., and revolving, like the others, in the direction N., W., S., E. This whirlwind must have fallen into the track pursued by the former, and probably both became afterwards blended together.

Mr. Redfield, Professor Dove, and Sir W. Reid, independently of each other, and nearly at the same time, ascertained, from the accounts of persons who had navigated the southern hemisphere, that in the whirlwind storms of those regions the rotation takes place in the order of the cardinal points N., E., S., W., or contrary to that in which the rotations are made in the North Atlantic, the axis of the storm having also a progressive motion from the equator obliquely towards the south pole. Such appears to have been the nature of the storm near the isle of Rodrigues, February, 1807, in which the Blenheim, the flag-ship of Sir Thomas Troubridge, foundered; for it is observed by Sir W. Reid, that the Harrier, brig of war (one of the squadron), by scudding before the wind from the 1st to the 4th of February, described about three-quarters of the circumference of a circle in the order just mentioned. And since the ships first received the wind from the north-east, it may be inferred that, by sailing south-westward faster than the storm advanced, they actually overtook it at its south-east side. A like circumstance occurred to the ship Neptune, during its voyage from Calcutta to the Cape, in 1835. From a French account of the hurricane which was felt at Mauritius in March, 1818, it appears that the wind began early in the morning to blow from S.S.E. and S.; but in about an hour it changed to E.; and at daybreak it became N.N.E. and N., and when the storm ceased it blew from N.W. These circumstances indicate a rotation in the order N., E., S., W., about an axis passing a little way to the north of the island, from nearly east to south-west.

But the most remarkable storm which Sir W. Reid has investigated is that which occurred in the Indian Ocean, in March, 1809, when the fleet, under the convoy of the Culloden and Terpsichore, suffered severely. The fleet, homeward bound from India, had got in lat. 21° S., when, on March 14, the hurricane became so violent that the ships were dispersed. By tracing the courses which they pursued, and also those of four ships which had sailed from the Cape to cruise near Mauritius, Colonel Reid found that the general movement of the storm from long. 80° E., where it was first felt, to long. 55° E., was from N.E. to S.W. nearly: from thence the path turned abruptly, and its direction afterwards was from N.W. to S.E. It therefore described a curve-line similar to that of the North Atlantic storm in August, 1837, but in a direction tending towards the south pole; and the manner in which the wind veered at each of the ships whose logs have been examined is capable of being represented by assuming that the rotation was, as in the preceding cases, according to the order of the points N., E., S., W.

From the 12th to the 15th of March the whole fleet appears to have been near the southern extremity of the vortex, and to have sailed in a direction parallel to the path of the axis. Seven of the ships, by *lying to* and falling to the southward, got out of the hurricane on the 15th; but on the 18th, one of them, the Huddart, fell into the southern branch of the line described by the axis, and crossed the northern extremity of the vortex as that axis moved south-eastward.

The Culloden, with part of the fleet, by sailing eastward, got, on the 15th, nearly to the centre of the vortex in the northern branch; on the 15th and 16th this ship scudded before the wind; but it afterwards changed its course to S.E., and on the 19th it got out of the storm. The ships which followed her probably continued to go before the wind; they thus kept near the centre of the storm, where they must have foundered.

In November of the same year, a hurricane which commenced in lat. 5° S. and long. 90° E., appears to have had little progressive motion; all the ships which were exposed to it experienced a temporary calm in the midst of the storm, and on the afternoon of one day, November 21, the wind veered rapidly quite round the horizon in the order N., E., S., W.

The whirlwinds in the Sea of China appear to differ in no respect from those which take place on the coast of North America. During a hurricane on the coast near Canton, August, 1829, when the East India Company's ship Bridgewater was driven on shore, the changes of the wind were successively from N. to E., and to E.S.E., ending at S.E.; therefore, if it be supposed that the course of the storm was nearly from E. to W., and that the ship was to the north of its centre, the rotation must have been in the order N., W., S., E. It has been ascertained that the rotations took place in the same order during the hurricanes of 1832 and 1835.

Little, comparatively, is known of the storms in the Pacific Ocean; but they also are of a rotatory character.

In higher latitudes the storms are irregular, probably because the vortices follow each other in the same direction and interfere with each other's gyrations. The great storm which, in 1838, was felt on the south coast of Ireland, and proceeded from thence along the west coast of Scotland, had all the characters of a whirlwind. It is stated by Sir W. Reid, that on the 14th of February, while at Cape Clear, the wind blew from S.E.; off Oporto the gale was from S.W.; at the same time, at the bottom of the Bay of Biscay, it was felt from S. and S.W.; and at the Shetland Islands, from the 16th to the 20th of February, the wind blew successively from S.E., S., and S.W. At Cadiz, between the 7th and 12th of February, the wind blew from S.W. and W.; and on the 16th, off Lisbon, there were heavy gales from S.W. to W.N.W. All these circumstances indicate a storm revolving in the order N., W., S., E., while its centre advanced in a line nearly from south to north. Professor Dove has remarked, in his paper already referred to, that in Prussia all storms are great whirlwinds, which continue during one or several days, sometimes as many as twenty, the rotation of the wind being generally in one direction.

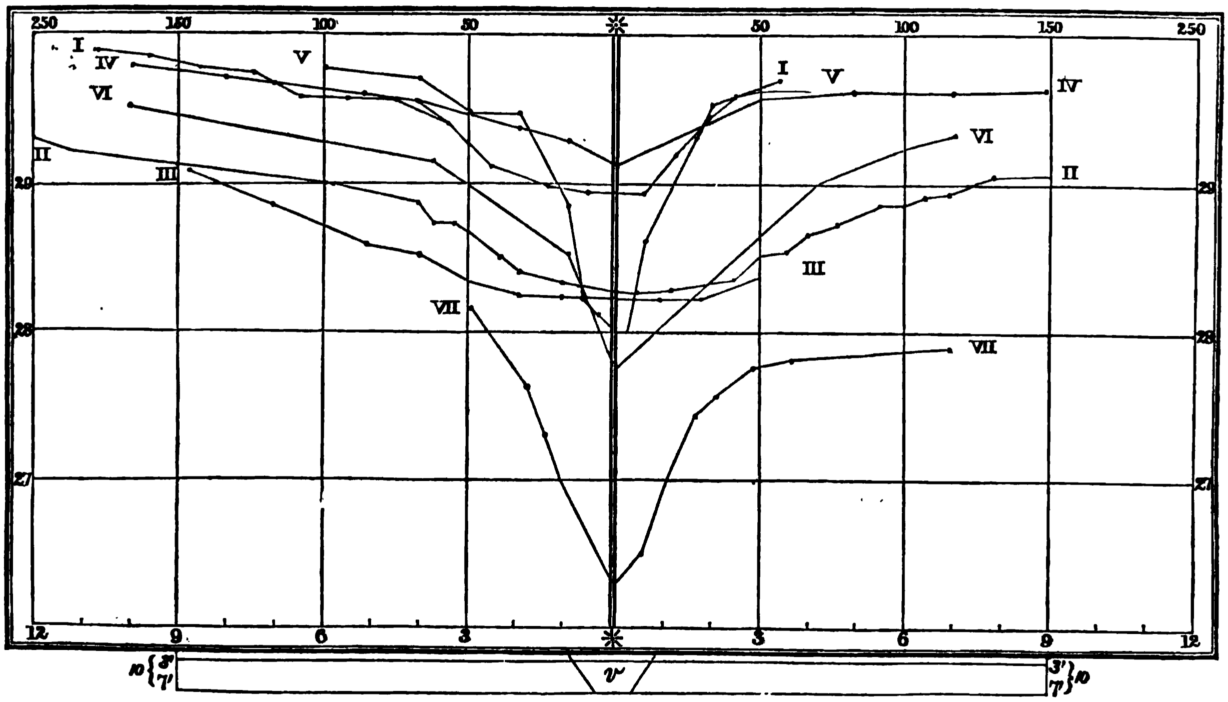
It resulted from the investigation and comparison of these and other facts by Mr. Redfield and Sir W. Reid, that a revolving storm, or Cyclone, as it is called, rotates, in the Northern hemisphere, from the east, or the right hand, by the north, towards the west, or *contrary* to the hands of a watch; and, in the Southern hemisphere, from the west, or the left hand, by the south, towards the east, or *with* the hands of a watch. Professor Dove expresses the same fact, beginning in both cases with the right hand, or the east side of the cyclone, by S., E., N., W. for the Northern hemisphere, and N., E., S., W. for the Southern.

The variations in the height of the column of mercury in a barometer afford, within the tropics, indications of the approach and the state of a whirlwind; the column is observed to fall gradually during part of the time that the storm continues at a place, apparently till the centre of the vortex has passed over, and then to rise as gradually. The depression of the column continues also during the movement of a storm from one region to another; the centrifugal tendency of the revolving particles probably opposing that of gravity, by which the particles would otherwise move towards the axis of rotation. Proofs of these circumstances are given by Sir W. Reid from observations made at Mauritius, during the hurricanes in March, 1819, and in February, 1824.

As the investigation of the subject has proceeded, the observation of the depression of the barometer during a revolving storm has been found to be of the utmost importance, as well in a philosophical as in a practical point of view. The fact is connected inseparably with the general history of the atmosphere. That a considerable decrease of pressure should be an effect of any unusual disturbance in it is a supposition so natural, that it at once occurred to those who first remarked that the weight of air surrounding us is not always the same. For the purpose of measuring these changes, the inventor of the air-pump, Otto Von Guerike attached a scale to the water barometer, which he also invented, and he records an observation that in the year 1660, the index pointed below the lowest mark on the glass tube, on which he had confidently affirmed that there was a great storm somewhere, and that, two hours afterwards a tempest was raging in the district of Magdeburg. As a more recent example, Dove mentions the great storm of January 17, 1818, which extended from the shores of England to Memel, and was felt throughout a region 240 German miles in length, and during which the barometer fell eight lines in as many hours, having also fallen between the 3rd and the 17th of January in all twenty-one lines, or an inch and three-quarters. The experience of the last two centuries indeed has so far confirmed the remark of Von Guerike, that the scales attached to our common barometers usually terminate with "very stormy." But its applicability is not confined to the temperate zone: in lat. 70° N., long. 70° W., the warning afforded by a considerable fall in the marine barometer, enabled the celebrated navigator Scoresby to avoid the dangers of a tempest which lasted two days uninterruptedly. Sir W. Reid, as we have just seen, established corresponding facts in relation to the revolving storms of the Indian Ocean; and in the regions of the trade winds, and of the monsoons, the numerous examples of greatly diminished pressure ushering in the typhoons and West India hurricanes are now well known.

The 'Law of Storms,' principally by the skilfully conducted and continued researches of Mr. Redfield and Sir W. Reid, having been brought into the condition explained in the preceding columns, and the latter, especially, having indicated to the seaman not only how he might, by applying the acquired knowledge of that law, avoid the dangers of hurricanes, but even profit by their intervention in his voyage, a new advance was given to the subject; a new explorer being added to those by whom it had been investigated, and who, indeed, had been pursuing his own researches contemporaneously with some of theirs. The late Mr. Henry Piddington, President of Marine Courts, Calcutta, communicated to the Asiatic Society of Bengal, in 1839, the first of an extensive series of memoirs, in which he discussed the phenomena of revolving storms in the Indian and Chinese Seas, as recorded in the log-books of the ships which had experienced them, and in various other documents. These having been first printed in the 'Journal' of the Society, Mr. Piddington published a valuable digest of their results, and of those obtained by his contemporaries, in a work entitled 'The Sailor's Horn-Book for the Law of Storms,' of which several editions appeared, the first in 1848 and the second in 1851. In the first edition of this work, the author proposed the designation of *Cyclone,* from the Greek Κυκλος, a circle, also the coil of a snake, for hurricanes, typhoons, revolving storms, and circular blowing gales in general, superseding, for nautical as well as scientific purposes, all the terms previously in use. This designation having been universally adopted, we shall employ it in the remainder of this article, premising, however, that the term 'whirlstorm' has been recommended by some as an apt English emphatic synonyme when required.

Mr. Piddington constructed, and published in his work, what he termed a barometrical chart, exhibiting certain numerical phenomena of seven cyclones, which, as being one of the most instructive graphical representations of physical facts we have ever seen, and as giving what may be called vertical sections of the cyclones, we have copied in the diagram annexed.



A few words in explanation are required. The double set of numbers and spaces at the top line of the diagram, forms a general scale of distances in miles from the centre of each cyclone. The double set at the bottom forms a scale of hours before and after the passage of the centre. The numbers and spaces at each side denote the heights of the barometer in inches. The Roman numerals refer to the cyclones enumerated in the following list, the barometrical observations taken as standards being such as were made on shore, which alone could be used in a construction of this description—a circumstance enhancing the value of the chart; few observations of the phenomena of cyclones, as may be supposed, having been made on the land.

The diagram thus comprises—

	Authority.
I. Madras hurricane	1836, Observatory records.
II. Mauritius	1836, Cols. Lloyd, Lewis; Reid.
III. Calcutta	1842, H. Piddington, 7th Memoir, 'Jour. As. Soc.,' vol. vii.
IV. St. Thomas, West Indies	1837, Professor Dove, in Part x. of 'Scientific Memoirs.'
V. Duke of York, Kedgeree, mouth of the Hooghly	1833, Mr. James Prinsep, 'Jour. As. Soc.,' vol. iv., Reid, p. 291.
VI. Havanah	1846, 'Bermuda Royal Gazette.'
VII. Madras	1841, Observatory Reports, 5th Memoir, 'Jour. As. Soc.,' vol. vii.

The principle on which the diagram is constructed, is to take without reference to the hour of the day or night at which it occurs, the lowest point of the barometrical depression in a cyclone, as the centre or axis of that storm. This is placed on double, or axis lines in the middle, and the fall and rise, and the time in which these occur are shown on a scale of hours below, and of inches to the right and left. We have thus the cyclones brought together and placed upon each other, as it were, for comparison, under exactly equal conditions as to time, and as to the fall of the mercury in that time. The scale of miles above will be presently explained.

And we are immediately struck with the fact, that there are evidently two distinct classes of cyclones, compared by Dove to deep ravines with precipitous sides, and to extensive valleys with gentle declivities, in one of which the fall and rise are more or less gradual, forming an easy curve, while in the others it forms not so much a curve but almost an angle, or rather the figures called by opticians caustic curves, and in these last cyclones the fall has been excessive and the fury of the tempest far beyond the average of such visitations. We may thus divide the storms into a first and second class; the first class being those of the greatest (excessive), and sudden falls near the centre.

There is also evidently another peculiarity, that is, that all the rapid part of the fall seems to begin at from three to six hours before the passage of the centre, and that before that time the fall even of the violent cyclones is comparatively gradual, and in fact approaches closely to the second class.

The scale which Mr. Piddington, after much consideration, found the nearest to the probable truth, is that marked in miles on the upper part of the diagram, though this is to be considered as by no means strictly a limit; for, as regards limits, he says it may possibly be found in the end that there are no strict ones at all, and that even the various extremes may be wider apart than the following table will indicate:—

An average fall of the barometer per hour of		Shows the distance of the centre from the ship to be in miles,	
From.	To.	From.	To.
0·020	0·060	250	150
0·060	0·080	150	100
0·080	0·120	100	80
0·120	0·150	80	50

The third decimal of the barometer heights is replaced by a cypher.

"I have not set down anything," Mr. Piddington remarks, in continuation, "for the centre division of our table, that is, from the centre to 3*h* before its passage, for it will be seen that the rate of fall per hour doubles after the cyclone has fairly begun and lasted six hours; and that then (from 3*h* to ‖, or from nine hours after the commencement up to the centre) it may either continue to fall at the same rate of about 0·1 per hour, or a little more, or that its rate of fall per hour may be, if it should be a cyclone of the first class, as 100 to 400, when compared with that of the former three hours; or, in other words, that it will now begin to fall four times as fast, or 0·40 per hour! We have plenty of instances of this, and even of a fall of more than 0·5 or 0·75 (half or three-quarters of an inch) in the hour! I doubt not that this peculiarity will fully account to the seaman for, and I hope put him well on his guard against, cases of sudden falls, which, if they occur at the beginning of cyclones, as they sometimes do, are warning enough, of course; but which may also advise him of his too near approach to danger of such imminence that we may at least say that no ship can hope to escape from it with her masts standing; and he should in such cases have the axes upon deck—a precaution too often neglected by young commanders and officers, who are apt to suppose that caution indicates fear, and they are sometimes afraid of being thought afraid of the storm. It will be remembered, also, that it is quite impossible by any previous rates of fall to estimate, when so near the centre, which of the classes of storms we have to deal with; and I repeat that what we have to do with our ship must all be done before this time."

Below the framing-line, at the bottom of the diagram, is represented in section, on a very small scale, the entire form of cyclones, as from Mr. Piddington's discussion of his own and other results it would appear to be—a disc, the thickness or height of which measures a very small fraction only of its diameter. The lines indicate the discs of cyclones of 300 miles in diameter, and of 10, 7, and 3 miles in height respectively, with a supposed vortex (*v*) at the centre, which has a calm of 10 miles at its base. "The reader," Mr. Piddington remarks, "may from this estimate what it would be if 5 or even 15 miles high, and how fallacious all our notions are apt to become when we consider these storms as whirling *columns*, and insensibly go on to liken them to waterspouts as to height, which it is evident they cannot at all resemble, since their size (diameter) may be said to have been in many cases estimated to a few miles with tolerable correctness; and in frequent instances the next stratum of clouds above the storm, either at rest or moving altogether differently, has also been clearly distinguished and noted: so that we may boldly affirm that at most the height (thickness is the more correct word) of the disc never exceeds 10 miles, and usually falls far short of it." The cyclone-disc, indeed, is sometimes so thin, that at or near the centre, whether calm or not, it has often been seen through, of which the following, in Mr. Piddington's opinion, are instances:—Dr. Malcomson, in describing a cyclone in the Arabian Sea, in which a ship was dismasted and in great danger, after alluding to the intensely dark masses of clouds that pressed down, as it were, on the troubled sea, states that, "In the zenith there was visibly an obscure circle of imperfect light of 10 or 12 degrees." In another storm, which was a true cyclone by its veering, and a tornado as to duration and violence, while all round the horizon was a thick dark bank of clouds, the sky above was so perfectly clear that the stars were seen. In the cyclone, one of the number investigated by Mr. Piddington, of October, 1849, in the Bay of Bengal, at the time of the passage of the centre over the lighthouse at False Point, Palmiras, or for about two hours of calm, the stars were seen very clear overhead, with a thick bank of haze all round. In this instance, also, the observers in several ships speak of a circle of light, or of its being much clearer overhead at the centre; "and this is exactly the appearance which should occur to an observer situated at the centre of a thin disc, as well as to one in the focus of a thick vortex." The phenomenon, in fact, is so constant, as to have received a name from the Spanish navigators, who call it "the eye of the storm."

We proceed to explain some popular designations connected with the subject, and the phenomena to which they more specifically relate:—

Tornado, a whirlwind, from the Spanish *tornar*, to turn, is the term given to a sudden and violent cyclonal storm, accompanied by lightning and thunder and heavy torrents of rain, as observed originally on the coast of Africa, and in the Spanish West Indies. Terrestrial bodies within its influence are violently displaced, or the ocean is strongly agitated: on land, forests, plantations, and buildings are destroyed; and at sea, ships are engulfed or driven on shore: the effects are of course the greatest near the circumference of the vortex, and the space within which they are felt varies in extent; sometimes the diameter of the area is several miles, and at other times it does not exceed one hundred yards. The approach of the storm is foreboded in the morning by the appearance, over the land, of dark clouds which move towards the sea, while a gentle breeze is blowing towards the shore: soon afterwards the rain comes down in torrents, and the lightning darting from the clouds resembles showers of electric matter. While the tornado is passing over a ship, which may be four or five hours from the first appearance of the clouds, the flashes cease, but the rain continues, and a loud crackling noise, occasioned by the electric fluid descending along the masts, is distinctly heard among the rigging. After the squall has passed beyond the ship, the lightnings again appear to descend in sheets as they did on its approach.

A less extensive whirlwind is frequently preceded by a remarkable tranquillity of the atmosphere and a sultry heat; when suddenly, within a circle of one or two hundred yards only in diameter, a revolving motion of the air commences, and is accompanied by thunder and rain: the velocity of the rotation gradually increases, and at length its violence is such as to tear up trees and destroy buildings which may be within the vortex. It may not continue longer than half an hour, but in that short time the damage is immense, and the loss of life is frequently considerable.

Typhoon (Greek τυφῶν, a whirlwind) is a name frequently applied to a tropical storm: it is also given to the hot winds which occasionally blow with great violence in Africa, Syria, Arabia, and Persia; and which are felt, though rarely and with much-diminished force, in the southern parts of Italy and Spain. It has been supposed that the Chinese designation for a cyclone, *Tyfoon*, was also originally derived from the Greek, but Mr. Piddington has shown, after the celebrated sinologist Dr. Morrison, that it is indubitably a Chinese word. The latter relates that there are in China "temples dedicated to the Tyfoon, the god (goddess?) of which they call *Keu woo*, 'the tyfoon mother,' in allusion to its producing a gale from every point of the compass, and this mother-gale, with her numerous offspring, or a union of gales from the four quarters of heaven, make conjointly a *taefung*, or tyfoon." The sirocco of Egypt and the coasts of the Mediterranean, the simoom of Arabia, and the harmattan of the coast of Guinea, are understood to be so many designations of the typhoon; all of them being supposed to originate in the same cause.

Frequently when the winds have a whirling as well as a progressive motion, columns of sand are raised and driven about with great rapidity; and Burckhardt observes that in Africa and the East the dust obscures the face of the sun, giving to the atmosphere a blue, a yellow, or a reddish tint. [DUST, ATMOSPHERIC.] M. de Humboldt occasionally observed columns of sand in motion in the interior of South America.

The fatal effects which have been said to result both from the masses of moving sand and from the supposed deleterious quality of the winds, are now considered as exaggerations: the inconveniences felt by men and animals during the continuance of the hurricane are chiefly such as arise from the heat and dryness of the air, and from the quantity of sand which is blown into the eyes. [SAMIELI; SIROCCO.]

Some short notices on the theory of cyclones, and probably allied phenomena, must conclude this article. In Sir J. Herschel's 'Report on the Reduction of Meteorological Observations,' presented to the thirteenth meeting of the British Association, 1843, after discussing the philosophy of what he calls winds of barometrical oscillations, arising from local and temporary causes prevailing over great areas simultaneously, and occasioning, eventually, an extensive atmospheric undulation, he applies the subject to the theory of cyclones in the following manner:—"Some of the principal of the phenomena of revolving storms would seem capable of explanation in this way of conceiving winds of oscillation, and in which they would become traced up, not to funnel-shaped revolving depressions in the nature of waterspouts, but simply to the crossing of two large long [atmospheric barometrical] waves running in different directions. The way in which a rotary movement in an ellipse or circle, or in in some other partly oval and partly rectilinear figure, may result from the combination of two rectilinear movements of advance and recess, will easily be understood by the analogy of the circular and elliptic polarisation of light, where rectilinear movements of the ethereal molecules are conceived to be similarly combined. [ELLIPTIC POLARISATION.] Some features in such storms are strongly in harmony with this view, namely, the fact that in them the direction of the wind at a given locality never makes more than one rotation, and not always that; and that in the central line of the storm's progress there is a simple and sudden reversal of direction. On the other hand, it must not be concealed that some features militate against it; for instance, the fact that such gales are stated always 'to revolve' in one direction, whereas, on this view of their origin, the changes of wind ought to be in opposite directions on opposite sides of the medial line."

M. Lartigue, in a paper on the storms of the Pyrenees, communicated to the French Academy of Sciences on the 3rd of December, 1855, and of which an abstract appears in the 'Comptes Rendus,' has some remarks on their analogy to the hurricanes of the intertropical regions, and of the seas adjacent to the coasts of the United States of America. In these he announces an explanation of cyclones substantially identical with that of Sir J. Herschel here given. Two illustrative diagrams represent a storm determined by winds the direction of which are perpendicular to each other, and another produced by winds having diametrically opposite directions.

The following important suggestion on the immediate cause of hurricanes, has been made by Sir J. Herschel in several of his works, both anteriorly and subsequently to the preceding: it is now extracted from 'Outlines of Astronomy,' 1849, par. (245), note:—"It seems worth inquiry, whether hurricanes in tropical climates may not arise from portions of the upper currents [of heated equatorial air] prematurely diverted downwards before their relative velocity has been sufficiently reduced by friction on, and gradual mixing with, the lower strata, and so dashing upon the earth with that tremendous velocity which gives them their destructive character, and of which hardly any rational account has yet been given. But it by no means follows that this must always be the case. In general, a rapid transfer, either way, in latitude, of any mass of air which local or temporary causes might carry *above the immediate reach of the friction of the earth's surface,* would give a fearful exaggeration to its velocity. Wherever such a mass should strike the earth, a hurricane might arise; and should two such masses encounter in mid-air, a tornado of any degree of intensity on record might easily result from their combination."

The manner in which this is related to the principle enunciated by Hadley to account for the trade-winds (col. 926), and developed by Dove in his Law of Rotation, will readily occur to the reader. Sir J. Herschel, when last noticing the subject, in his 'Treatise on Meteorology,' alludes to that principle and its development, as applied to this specific class of aërial movements by Professor Taylor, as affording "a complete account of all the characters of cyclones."

In the article WATERSPOUTS, the opinion has been expressed, that probably phenomena of several distinct classes are at present confounded together under that appellation. Sir J. Herschel, contravening, as it would appear, his former opinion, now regards them as of the nature of cyclones. Mr. Piddington, as we have seen, carefully discriminates between them, at least as to form, on account of the discoidal character of the one set of phenomena and the columnar figure of the other; notwithstanding his admissions that waterspouts have the characters of whirlwinds, and exhibit them manifestly when they advance upon the land. It seems difficult to refer to the same causes a disc of which the thickness or height is a very small fraction of its diameter, as in cyclones, and a slender column of which the diameter is an equally small fraction of the length or height, as in the waterspouts observed on land by Major Sherwill, and at sea by the Rev. Dr. Scoresby. The former describes the powerful attraction, which he naturally attributes to electricity of the summit of the mountain Tonglo, for certain waterspouts. This is strongly corroborated by some facts stated by another Indian observer, Captain Montgomerie, B.E., of the Trigonometrical Survey of India, who found, on the Pir Punjal peaks of the Himalaya, south of Cashmere, at elevations of from 13,000 to 15,000 feet, the electricity to be so troublesome, even when there was no storm, that it was necessary to carry a portable lightning conductor for the protection of the theodolite. Still, however, waterspouts, if of mere mechanical origin,—if merely excessively rapid gyrations of condensing vapour or closely approximated globules of water,—might, and in all probability would, exhibit powerful electric action. If their form be so sustained, enormous friction of the particles must ensue, and a corresponding amount of electricity be developed; the entire column would be strongly charged, and would eventually attract and be attracted by the ground. The sudden precipitation of the water may be the united effect of the electrical discharge and of the destruction of the sustaining gyration by contact and friction with the fixed mass of the land. But everything tends to show that our ideas of waterspouts are inexact, and that the subject of their origin and nature and relation to mere gyrations of the air, is in need of that critical discussion which all the complex phenomena of nature require, and but few of them have received.

The force of the winds has been noticed under AËRODYNAMICS, and the means of measuring it described under ANEMOMETER. In Mr. Piddington's *Sailor's Horn Book,* a catalogue of other works on the Law of Storms will be found, and on that subject, and that of the winds in general, may be consulted (in addition to the works and memoirs which have been cited in this article), Admiral Beaufort's *Remarks on Revolving Storms;* and also Mr. W. R. Birt's *Hurricane Guide;* and his article on Atmospheric Waves in the *Admiralty Manual of Scientific Enquiry.*

WINDAGE is the quantity by which the bore of a gun, mortar, or howitzer exceeds that of the shot or shell which is to be discharged from it.

The deviations of shot and shells from a truly spherical figure, and the inequalities in the bore of the ordnance, were formerly considerable; and on these accounts it was necessary to have a sufficient difference between the presumed diameters of the ball and bore, in order to ensure the possibility of making the former enter into the latter: it followed, from the greatness of this difference, which in the British service was about one-twentieth of the diameter of the bore, that much of the fired gunpowder escaped without producing any impulse on the shot, and that the latter was driven from one part of the surface of the bore to another; so that, on being expelled from the gun, it deviated widely from the intended direction of its flight.

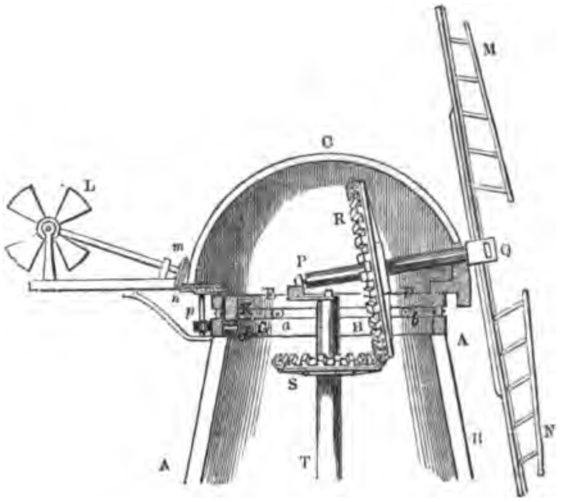
From the year 1775, when Dr. Hutton made his first experiments on the velocities of shot, the disadvantage attending a great windage was known, and a diminution of its quantity was proposed; but the precise amount of the force lost by it was not ascertained till the years 1784 and 1786, when experiments were made for the purpose, in part, of determining that important circumstance. From these it appeared that about one-fifth of the charge of powder was lost by a windage equal to ·06 inch, or $\frac{1}{33}$rd of the calibre (= 2 inches), and a further loss, amounting to between $\frac{1}{7}$th and $\frac{1}{4}$th of the charge, was occasioned by an increase equal to $\frac{1}{10}$th of an inch above the former windage.

The correct geometrical forms which are now given to the balls, and also to the bores, permit the windage to be reduced much below its former value; it now varies only from $\frac{1}{43}$th to $\frac{1}{32}$nd of the calbre, in no case exceeding 0·2 inch even for the largest guns, and is still in process of reduction, as the manufacture of shot and shells advances in precision.

WINDLASS, an apparatus for raising a ship's anchors. It is placed forward, as near to the hawse-pipe as convenient. A machine subject to such violent strains as those which constantly affect a ship's cable when in use, is necessarily built of the soundest oak and the best iron in all the parts constructed of those materials, and is secured by stout vertical pieces of timber called *bitts,* which rise above the deck and serve the purpose of fastenings for the cable, which has first two or three turns round the barrel of the windlass. The cable is wound either by means of handspikes or a winch. As windlasses for ships are so varied in form and principles, it is unnecessary to enter into detail. These dimensions have of late years been greatly modified in consequence of the alteration of form in ships, and especially steamers, where the narrowness of the bows admits but of little length to any cable-raising contrivance. [GROUND-TACKLE.]

WINDMILL is a building containing machinery for grinding corn, pumping water, sawing wood, or for any purpose depending on wheel-work, to which motion is communicated by the impulse of the wind. Windmills are of two kinds: in one, the wind is made to act upon vanes or sails, generally four, which are disposed so as to revolve by that action on an axis which is nearly horizontal, in a plane which is nearly vertical; and in the other, the axis of revolution being precisely vertical, any point on the surface of the vane revolves in a horizontal plane. The former is called a vertical, and the latter a horizontal windmill.

The building is generally a wall of timber or brickwork in the form of a frustum of a cone; and the smaller kind of mill when formed of timber is capable, by means of a lever, of being turned round horizontally on an axis, in order that the plane in which the radii or arms of the sails revolve may be placed perpendicularly to the direction of the wind, for the purpose of allowing the latter to act upon the sails in the most advantageous manner. In other kinds of mills the conical wall, A B, is terminated above by a wooden dome, C, which is capable of revolving horizontally upon it. A ring, E F, of wood, forming the lower part of the dome, rests upon a ring, G H, of the same material at the top of the wall, and the surfaces in contact being made very smooth, the former may easily be turned round upon the latter, being prevented from sliding off by a rim which projects from it, as at K, and descends over the interior circumference of the lower ring. The revolution is however facilitated by placing between the two rings of wood one of metal, in which are fixed four or six small wheels or rollers, as *a b*, on horizontal axles. The weight of the dome is supported on these rollers, which turn by its motion. Small wheels or rollers, as *d*, are also fixed on vertical axes in the projecting rim just mentioned; and as the dome revolves the circumferences of these rollers press against and turn upon the interior faces of the ring which is fixed on the top of the wall.



The dome in turning carries with it the windsails, M N, and their axle, P Q; and thus the latter may be made to coincide with the direction of the wind, or the plane in which the radii of the sails turn may be made perpendicular to that direction. The revolution is sometimes accomplished by the force of a man applied to a winch near the ground. An endless rope, as it is called, or one whose ends are spliced together, passes under a pulley on the axle of the winch, and over one near the top of the mill; and the latter pulley in revolving gives motion to a wheel and pinion, the last of which works in teeth on the exterior circumference of the ring which forms the lower part of the dome.

But in general the wind itself is made to turn the dome of the mill so that the sails may continue in the proper position with respect to the direction of the wind. For this purpose there is provided a set of small vanes, L, which are situated at the extremity of a long horizontal arm projecting from the dome in a plane passing through the vertical shaft of the mill, and on the side opposite to the great sails. These vanes turn on a horizontal axis at right angles to that plane, and are set in motion by the pressure of the wind when the latter deviates from the plane of their motion, or from a plane perpendicular to that in which the radii of the great sails revolve. A pinion on the axis gives motion to a wheel, and the axle of this last carries a pinion, *m*, whose teeth work in those of the wheel *n*; the axle of this last carries a pinion, *p*, whose teeth work in others which are formed on the exterior circumference of the ring G H, forming the base of the dome. By this means the dome is made to revolve horizontally, so as always to present the axle (P Q) of the windsails in the direction of the wind. It is to Sir W. Cubitt that we are indebted for this simple but invaluable improvement in the details of windmill machinery. Strangely enough, it has never yet been applied in Holland or Northern Germany.

This axle is usually inclined about 10 degrees to the horizontal line. It is supported at the inner extremity, P, which is at or near the centre of the base of the dome, on the top of the vertical shaft, S T, of the mill, and near the opposite extremity on a block under a perforation in the dome. The axle passes through this perforation, and the radii, or arms of the sails, are affixed to it on the exterior; the axle and the sails which it carries revolve with the dome about the lower point of support. A toothed wheel, R, is fixed perpendicularly on the axle, and revolves with it by the pressure of the wind on the sails; and the teeth or cogs of this wheel drive those of a lantern or pinion, S, on the vertical shaft of the mill. To this shaft, as an axle, the upper millstone is fixed, so as to revolve with it in a horizontal position; and the corn being placed in a hopper, or funnel, is allowed to run from thence between the stones through a small channel, and through a perforation about the centre of the upper one. The lower millstone is stationary, and the corn being ground, the meal is received in vessels underneath. The principal wheel, R, is furnished with a *brake*, by which its motion may be checked or stopped at pleasure.

The four radii, or *whips*, as they are called, of the sails, are let into the axle at right angles to it and to one another, so that a plane passing through them will decline about 10 degrees from a vertical position. Into each of these radii or arms are fixed a number of staves of wood, each five or six feet long, at right angles to it and inclined to the plane passing through the arms, but approaching nearer to coincidence with such plane, as they are more distant from the axle. The ends of these staves are inserted in a rod of wood extending nearly the whole length of the arm; and thus there is formed a sort of lattice-work on which canvas is spread to receive the action of the wind. In most cases each radius or whip of a windmill sail is about thirty-three feet in length from the axle to its extremity.

The variations in the force of the wind require that the quantity of canvas on the sails should be varied accordingly; and the contraction as well as the expansion of a sail is usually effected by means of ropes fastened to it in three places or more. These ropes may be either drawn tight or relaxed as required; but for either purpose it is necessary that the mill should for a time be stopped; and as the stoppage is attended with great inconvenience, several methods have been devised for rolling and unrolling the sails while in motion. One of these, which was invented by Mr. Bywater, consists in the application, on each arm or whip, of a cylinder or roller to which the canvas is attached: this extends the whole length of the arm, and has a toothed wheel at the extremity nearest to the axle; the teeth of this wheel work in those of two other wheels, and the motion of one or the other of these being stopped, the cylinder rolls up or unrolls the canvas, being made to turn on its axis by the action of the wind on the sail. Several methods have also been proposed for equalising the action of the wind on the sails of a mill, and they consist generally in the employment of a series of valves fixed in the frame work of each sail. These valves revolve on pivots which are let into the frames; and as the force of the wind increases, they present, in turning, less of their surfaces to its action, so that the pressure is rendered nearly equable. None of the methods seems however to be in use, probably on account of the great additional expense with which the construction would be attended. Of late years wooden lattices working somewhat on the principle of the Venetian blinds, have been used instead of canvas for the sails of windmills, and their angle towards the wind is regulated by a species of governor fixed on the main shaft; but there seem to be mechanical difficulties in the way of this system which have hitherto opposed its general adoption.

A horizontal windmill is a great cylindrical frame of timber, which is made to revolve about a vertical axis, and its convex surface is formed of boards attached in vertical positions to the upper and lower parts of the frame. The plane of each board is oblique to the lines in which the wind impinges on it, the direction in which the latter blows being supposed to be parallel to the horizon; and the whole is inclosed in a fixed cylinder having the same vertical axis as the other: this consists of a screen formed by a number of boards which are disposed so that, in whatever direction the wind may blow, it may enter between them on one side only of a vertical plane passing through the axis. The wind thus entering acts upon the oblique surfaces of the boards about the interior cylinder on one side of the axis, while it is, in a great degree, prevented by the screen from acting upon the boards on the opposite side; these boards therefore meet with small resistance when, during each revolution, they come up towards the quarter from whence the wind blows. In horizontal mills one board may receive an impulse equal to that which the wind communicates to a sail of equal area in a vertical mill; but in the latter all the sails are acted upon equally at the same time, whereas in the former only one or two can receive the impulse of the wind, and there is always, besides, some resistance experienced in returning against the wind. Mr. Smeaton estimated that the power of a horizontal mill was only about one-tenth of the power of a vertical mill, the dimensions of the sails or vanes being equal in both; but it is observed by Sir David Brewster that in this estimate no account is taken of the resolved part of the wind's force which presses the pivot of the axle against its support, and which is lost on the sails of the vertical mill; and he concludes that the power of the latter is not more than three or four times as great as that of a horizontal mill. The effective power of the vertical mill is however so much greater than that of the other kind, that the latter is now seldom constructed.

The effective force of the wind in turning the sails of a mill is investigated in the article WINDSAILS.

(See Brewster's edition of *Ferguson's Lectures;* Smeaton, *On the Power of Wind and Water;* Borgnis, *Traité Complet de Mécanique;* Leendert van Naturus, *Groot Volkomen Moolenboek*, &c.)

WINDOW. Though almost unknown in ancient architecture, at least in the religious and other monumental structures of the Egyptians, Greeks, and Romans, which were not of a nature to require them, windows are exceedingly important features in the Gothic and other styles, and that not only for one, but every class of buildings. In the Pointed Gothic more especially they are so characteristic by their general forms and proportions, as well as their decoration and details, as to be in that style equivalent to what the orders are in the temple architecture of antiquity: the division of Gothic into periods, as First, Second, and Third Pointed, or Early-English, Decorated and Perpendicular, depends indeed mainly on the window-forms. [Gothic Architecture; Romanesque Architecture.] Gothic without windows would be as deficient in expression as Grecian architecture without columns. Grecian architecture, on the contrary, hardly admits windows, since, instead of adding to, they rather mar its expression, and detract from its character. There are, indeed, some examples of windows, for instance in the Erechtheum at Athens, yet no more than barely to serve as authorities, and to show how apertures of the kind were designed. Besides being of exceedingly rare occurrence in Grecian architecture, the windows themselves were very few in number, and never placed so as to form more than one tier or story of them; consequently the effect was totally different from that attending two or more continuous ranges of windows placed one over the other. This arrangement was, however, adopted by the Romans in such buildings as their amphitheatres, and also in their basilicas, and in the former with a very fine effect, as may be seen in the Colosseum at Rome, and the amphitheatres of Verona and Nîmes.

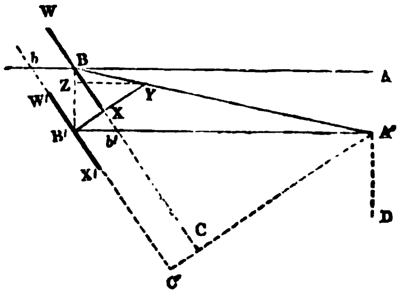
It is one very great advantage of the Pointed Gothic style, that there the windows derive strong architectural expression from the apertures themselves; which, with the mullions, transoms, and tracery inserted in them, mainly form the design and decoration; while the external mouldings and ornaments contribute to them only in a subordinate degree. Consequently, if otherwise quite plain, the windows can never appear mere vacant spaces. Widely different is it in those styles where the ornamental design is confined to the mere exterior or framing of the aperture; in which, however they may be so decorated, the openings will, if of very large dimensions, always have a vacant look, and the glazing of the windows will appear to be in want of adequate support. It is another advantage peculiar to Pointed Gothic, that it allows windows to be of any dimensions—of the smallest as well as the largest, and windows of very different sizes and proportions to be introduced into the same elevation. [Gothic Architecture; Oriel.]

In the Italian style, windows, by which we mean the window opening and the *dressings* around them, which last term is employed to designate the whole of the decoration bestowed on such apertures, or, in other words, the entire "composition," form as essential a feature as in Gothic, though admitting of comparatively little of the diversity of size, form, and character. French, German, and English Renaissance exhibit much greater variety of illustration than the Italian. [Renaissance Architecture; Elizabethan Architecture.] In Italian buildings of the better class, the principal story, or that immediately over the basement or ground-floor, is marked by windows more highly decorated and of loftier proportions than the rest. For these the apertures are generally made from 2 to 2½ squares, or even something more, that is, their height is something more than double their breadth; those on the next floor rather less than two squares; and for the third they are made *mezzanines*—either a perfect square or very little more. The character and proportions of ground-floor windows depend very much upon the manner in which that part of the elevation is treated; if it be no more than a low rusticated basement, the windows will only be of mezzanine form, without dressing; or at the most a few mouldings surrounding the apertures, the rusticated surface of the wall itself here producing a sufficient degree of finish and decoration; or if more be required, it is obtained by distinguishing the rustics around the windows, making them smooth if the others be rough, and *vice versâ*. Thus, while the windows are essential, they are still kept subordinate features in the design. What has been said in regard to the sequence of the different tiers of windows in an elevation, is to be understood only generally, there being many exceptions, and not a few anomalous cases. In the façade of the Palazzo Massimi at Rome, one of Peruzzi's best works, there are two tiers of mezzanine windows above those of the principal floor; in the celebrated Palazzo Farnese, on the contrary, the second-floor windows (which are also the uppermost) are somewhat loftier than the others, at least in their apertures, owing to these last being arched, and are further remarkable as having pediments, which are seldom used for windows higher up than the first floor. In Sangallo's façade of the Palazzo Sacchetti, there is a range of mezzanines between the windows of the first and the uppermost floor, and instead of being made principal in the design, the former are considerably less than those of the ground-floor, and are narrower at top than at bottom. The façade of the Palazzo Negroni, by Ammanati, is similar in its general character to the preceding, there being a row of mezzanine and square windows between the first and third floor; and it also resembles it in the importance given to the ground-floor windows. In regard to windows of the last-mentioned class, the Palazzo Buoncompagno at Rome, a work attributed to Bramante, offers an unusual example, for there the lower floor and its windows are made the next principal features after those immediately above them: in both the apertures themselves are round-headed, with imposts and archivolts, but flanked by pilasters supporting an entablature, whereby the general form of the *chambranle*, or dressing, becomes square-headed; the chief difference between these two tiers of windows is, that those above have pediments (alternately angular and segmental), while the others have none. Triple, or Venetian windows, as they are called, and grouped windows, are sometimes introduced in Renaissance buildings with excellent effect; and where a great degree of magnificence is desired, caryatides are substituted for columns as decorations. From the time of Palladio, balustrades have been added to windows, adding often greatly to their picturesqueness of character, but sometimes with a very different result. [Italian Architecture; Renaissance.]

WINDS, TRADE. [Wind.]

WINDSAILS are the vanes, generally four in number, which, being turned by the action of the wind, give motion to the machinery of a mill. The wind being supposed to blow in a direction parallel to the axis about which the sails are to revolve, it is evident that the plane of each sail must have a certain inclination to that axis, or to the plane of the revolution, in order that a resolved part of the wind's force may act in the latter plane perpendicularly to the radii or arms which carry the sails so as to turn them constantly in one direction about the axis. If the pressure of the wind on the sails, supposed to be at rest, were to be alone considered, the determination of the angle which the plane of each sail should make with a plane perpendicular to the axis, or to the direction of the wind, in order that the pressure might be a maximum, would be comparatively easy. For by the resolution of forces it is easily seen that the pressure perpendicular to the radii, and in the plane of their revolution, varies with the term $\sin^2\theta\cos\theta$, where θ is the angle which the sail, supposed to be a plane surface, makes with the wind or with the axis of revolution: and the differential of this quantity being made equal to zero, the value of θ is found to be 54° 44′ nearly.

But it is evident that the effect of the wind in giving a revolving motion to the radii must depend on its pressure, and also on the velocity of the surface against which it acts; and the angle which the plane of the sail should make with the direction of the wind, when its pressure on the sail in motion is a maximum, must be determined by an investigation similar to that which follows.



Let AB, $A'B'$, parallel to one another, represent the direction of the wind; WBX, $W'B'X'$, also parallel to one another, be two positions of a section of the sail, which by the pressure of the wind is made to move so that B, B', are in a line perpendicular to AB. Now if it be supposed that $A'B'$ is the space described by a particle of air while B would move to b (or b' to B') in the same direction, or from B to B' in a direction perpendicular to AB; the lines $A'B'$ and $b'B'$ will, respectively, represent the velocities of the wind and sail in directions parallel to $A'B'$, while BB' will be the velocity of the sail in the direction of this last line. Draw $A'C'$ perpendicularly to WX or $W'X'$, produced, and meeting the former line in C; then $A'C'$ and CC' will be respectively the velocities of the wind and sail perpendicularly to the line WX or $W'X'$, and consequently $A'C$ will be what is called the velocity of the wind in the sail. Therefore, the pressure of a fluid being proportional to the square of the velocity, the pressure of the wind in the direction $A'C'$ will vary with $A'C^3$; and this being resolved in the direction $A'D$ or BB', will be expressed by $A'C^2\cos CA'D$, or $A'C^2\sin B'Bb'$. But $A'B$ being constant, $A'C$ varies with $\sin A'BC$; therefore the effective pressure of the wind will vary with $\sin^2 A'BC\sin B'Bb$.

Let the angle $A'BB'$ be represented by a, $B'Bb'$ by θ; then $A'BC = a - \theta$, and the expression for the pressure becomes

$$\sin^2(a-\theta)\sin\theta.$$

Making the differential of this expression equal to zero, and reducing, we have

$$\tan(a-\theta) = 2\tan\theta,$$

when the pressure is a maximum.

Draw $B'XY$ perpendicular to BC, so that $B'X$ and XY may respectively represent $\tan(a-\theta)$ and $\tan\theta$; and let $A'B'$, BB' be respectively represented by v and by v'; then

$BX = v'\cos\theta$, $B'X = v'\sin\theta$,

$XY\ (= 2B'X) = 2v'\sin\theta$, and $B'Y\ (= 3B'X) = 3v'\sin\theta$.

Again, draw YZ perpendicular to BB′, or parallel to A′B′; then

$\mathrm{B'Z}(=\mathrm{B'Y}\cos \mathrm{BB'Y}) = 3v' \sin^2\theta,$

$\mathrm{YZ}(=\mathrm{B'Y}\sin \mathrm{BB'Y}) = 3v' \sin\theta\cos\theta,$ and

$\mathrm{BZ}(=v'-\mathrm{B'Z}) \quad = v'-3v'\sin^2\theta.$

But by similar triangles, $\mathrm{BZ} : \mathrm{ZY} :: \mathrm{BB'} : \mathrm{B'A'}$, that is

$v'-3v'\sin^2\theta : 3v'\sin\theta\cos\theta :: v' : v;$

whence $v-3v\sin^2\theta = 3v'\sin\theta\cos\theta.$

Multiplying each term by v, and for v^2, the first term, substituting its equivalent $v^2\sin^2\theta + v^2\cos^2\theta$, we have

$v^2\sin^2\theta + v^2\cos^2\theta - 3v^2\sin^2\theta = 3vv'\sin\theta\cos\theta;$

or simplifying, and dividing by $\sin^2\theta$, we get

$-2v^2 + v^2\,\mathrm{cotan}^2\,\theta = 3vv'\,\mathrm{cotan}\,\theta,$

which reduced as a quadratic equation, with respect to θ, gives

$$\mathrm{cotan}\,\theta\,(=\tan \mathrm{ABX}) = \frac{3v'}{2v} + \left(2 + \frac{9v'^2}{4v^2}\right)^{\frac{1}{2}}.$$

The angle ABX will evidently depend upon the relation between v', the velocity of the sail, and v, the velocity of the wind: if $v'=0$, or the sail is at rest, we should have $\tan \mathrm{ABX} = \sqrt{2}$, that is, the angle ABX would, as above, be equal to 54° 44′ nearly; and when $v'=v$, the formula gives ABX = 74° 19′ nearly. It follows that as the velocity of the revolution increases, the inclination of the section WX to the wind, or to the axis of rotation, should be increased. Since, therefore, the velocity of the sail continually increases from the axis to the extremity of the radius or arm which carries it, it is evident that the sail, instead of being a plane, ought to have a curved surface such that the inclination of the section to the direction of the wind may increase with its distance from the axis conformably to the values which would be given by the above formula, the ratio between the velocity of the wind and sail at any given distance from the axis of rotation being known or assumed. It was observed by Mr. Smeaton that the velocities of the sails at their extremities are often more than twice as great as that of the wind. From several experiments which were made on a great scale by the same engineer, it was found that the effect is very advantageous when the inclinations of the axis, or the direction of the wind, with a section of the sail taken perpendicularly to the revolving arm at different distances from the axis, were as in the ollowing table:—

At one-sixth of the length of the arm			72°
At one-third	„	„	71°
At one-half	„	„	72°
At two-thirds	„	„	74°
At five-sixths	„	„	77½°
And at the extremity		„	83°

Mr. Smeaton found also that when each sail is broader at the further extremity than near the centre, the effect is greater than when it has the form of a parallelogram; and that the most advantageous breadth at the extremity is one-third of the length of the arm.

There is a certain limit to the quantity of sail which a windmill can carry with advantage; and from Mr. Smeaton's experiments it results that, when the surfaces of all the sails exceeds seven-eighths of the area of the circle described by each arm in one revolution, the velocity is diminished; probably from the want of sufficient openings by which the wind, after impact, may escape. Mr. Smeaton also found that the ratio between the velocities of windmill sails when unconnected with the machinery, and when loaded so as to produce the maximum effect, is variable; but, in general, that ratio is as 3 to 2. The velocity of the sails when the effect is a maximum varies nearly with the velocity of the wind.

The form and position of the sails remaining the same, the load or resistance when a maximum, varies nearly with the square of the velocity of the wind; and the maximum of resistance which sails of similar figures, and in similar positions, will overcome at a given distance from the centre of motion, will vary with the cube of the radius or arm of the sail.

WINE. The chemistry of wine presents many points of interest, and may be treated of independently of its history, manufacture, commerce, and uses.

In the juice of the grape, fermentation is excited by the access of air, alcohol and carbonic acid being formed by the decomposition of the sugar contained in the fluid—

$$\underbrace{C_{12}H_{12}O_{12}}_{\text{Sugar.}} = \underbrace{2C_4H_6O_2}_{\text{Alcohol.}} + \underbrace{4CO_2}_{\text{Carbonic acid.}}$$

The process once commenced, continues independently of any further influence of the air. In addition to the alcohol and carbonic acid formed by the fermentation of the juice, there is also produced a yellow or gray insoluble substance, containing a large quantity of nitrogen. It is this body which possesses the power of inducing fermentation in a new solution of sugar, and which has in consequence received the name of *ferment*. [FERMENT.] The alcohol and carbonic acid are produced, as above indicated, from the elements of the sugar; but the ferment is formed from those azotised constituents of the grape-juice which have collectively been termed *gluten*. [GLUTEN.] Gluten dissolved in pure water undergoes a process of decomposition; but the decomposition which it suffers in an isolated state, and that which it undergoes when dissolved in a vegetable juice, belong to two different kinds of transformations. There is reason to believe that its change to the insoluble state depends on an absorption of oxygen; for its separation in this state may be effected under certain conditions by free exposure to the air without the presence of fermenting sugar. It is known also that the juice of grapes, or vegetable juices, in general become turbid when in contact with air before fermentation commences; and this turbidity is owing to the formation of an insoluble precipitate of the same nature as ferment. The oxygen consumed in the fermentation of wine or beer is not taken from the atmosphere, though the access of this is necessary to excite it in the first instance. Gluten seems to act towards sugar as diastase does towards starch, namely, imparts that impetus to it which enables it to alter its condition. When both gluten and sugar are present in a liquid, fermentation will go on till the decomposition of one or other be complete. When the quantity of ferment is too small in proportion to that of the sugar, its fermentative putrefaction will be completed before the transformation of all the sugar is effected. Some sugar here remains undecomposed, as the cause of its transformation is absent, namely, contact with a body in a state of decomposition: this happens in the *vins de liqueurs*, the *fruity* or sweet wines. But when the quantity of ferment predominates, a certain quantity of it remains after all the sugar has fermented, its decomposition proceeding very slowly on account of its insolubility in water. This residue is still able to induce fermentation when introduced into a fresh solution of sugar, and retains the same power until it has passed through all the stages of its own transformation. Hence a certain quantity of yeast is necessary in order to effect the transformation of a certain portion of sugar; not because it acts by its quantity in increasing any affinity, but because its influence depends solely on its presence, and its presence is necessary until the last atom of sugar is decomposed.

Climate and soil greatly modify wine both in kind and quality. Differences, however, in the vintage and manufacture often determine the character of wines made in the same district, and cause them to widely differ from each other in odour, flavour, and even colour. Such differences often occur spontaneously, as in the case of amontillado.

The quantity of *azotised matter* in the juice seems to be the same in whatever part the grapes may grow; at least no difference has been observed in the amount of yeast formed during fermentation in the south of France and on the Rhine. The grapes grown in hot climates, as well as the boiled juice obtained from them, are proportionally rich in sugar. Hence, during the fermentation of the juice, the complete decomposition of its azotised matters, and their separation in the insoluble state, are effected before all the sugar has been converted into alcohol and carbonic acid. A certain quantity of the sugar consequently remains mixed with the wine in an undecomposed state, the condition necessary for its further decomposition being absent. The azotised matters in the juice of grapes of the temperate zones, on the contrary, are not completely separated in the insoluble state when the entire transformation of the sugar is effected. The wine of these grapes, therefore, does not contain sugar, but variable quantities of undecomposed gluten in solution. This gluten gives the wine the property of becoming spontaneously converted into vinegar when the access of air is not prevented; for it absorbs oxygen and becomes insoluble, and its oxidation is communicated to the alcohol, which is converted into acetic acid. By allowing the wine to remain at rest in casks with a very limited access of air, and at the lowest possible temperature, the oxidation of this azotised matter is effected without the alcohol undergoing the same change, a higher temperature being necessary to enable alcohol to combine with oxygen. As long as the wine in the stilling-casks deposits yeast, it can still be caused to ferment by the addition of sugar; but old well-layed wine has lost this property, because the condition necessary for fermentation—namely, a substance in the act of decomposition or putrefaction—is no longer present in it. In hotels and other places, where wine is drawn gradually from a cask, and a proportional quantity of air necessarily introduced, its eremacausis—that is, its conversion into acetic acid—is prevented by the addition of a small quantity of sulphurous acid. This acid, by entering into combination with the oxygen of the air contained in the cask or dissolved in the wine, prevents the oxidation of the organic matter.

A knowledge of the facts just mentioned enables us to comprehend the nature and object of the practices adopted empirically for the preservation of wine; above all, of those which are requisite to prevent it passing into the state of acetic acid, to which the wines of northern countries, or poor weak wines, are most prone. Thus, the processes of racking, sulphuring, fining, mixing, bottling, and keeping in cellars the temperature of which is low, are obviously all directed against the occurrence of the *acetous* fermentation, as they are mostly inadequate to check the *vinous* fermentation, and indeed altogether unnecessary, since so long as the vinous fermentation is going on—that is, as long as the alcohol continues to be generated—the wine is gaining in quality. Once begun, the presence of atmospheric air is in nowise necessary for the continuation of the vinous fermentation; in fact, the more thoroughly it is excluded the better, for while the vinous fermentation, by which the wine is ameliorated, goes on, the acetous fermentation cannot commence.

From the above facts, established in the main by Liebig, it appears that while the azotised matter (gluten) in grapes, wherever grown, is a fixed quantity, the acids and saccharine matter are variable. When there is more saccharine matter, as in Rivesaltes, Frontignan, and Tokay, than there is gluten to transform into alcohol, a portion of undecomposed sugar remains, sufficient not only to give that taste which has acquired for them the name of *sweet* wines, but also to exert the usual preservative power of sugar, when present in large quantities, and resist decomposition. Thus, Muscadine wine has been kept two hundred years; Mountain, buried at the time of the Fire of London, and disinterred in 1811, was excellent; and old Tokay, called *vino vitrauno*, is in perfection at the end of a century. This wine needs neither sulphuring nor fining (Schams, 'Ungarns Weinbau,' erster band, p. 75); the casks are hermetically bunged; and the reason is obvious. To the juice of grapes grown in colder climates or cold seasons, sugar, especially starch-sugar, is added at the beginning of the fermentation, in order to consume all the leaven. Also to wine which it is apprehended is about to become sour, or *pricked*, as the first sign of its becoming acetified is termed, sugar is also added; but if vinegar has really been formed, this introduction of sugar, so far from hindering, only hastens the further transformation, as the presence of vinegar is the most powerfully disposing agent to this change.

The odoriferous principle, or *bouquet*, of wines, appears to be due to peculiar ethers, or Ethereal Salts, and, according to Winckler, to combinations of volatile fragrant acids with a nitrogenous base of balsamic odour. The conditions of the formation and of the decomposition of these compounds are not very well understood at present; some of the ethers, however, can be formed artificially.

The intoxicating quality of wine is, of course, due to the *alcohol*, the cause of the production of which has already been described. The method of ascertaining the amount of alcohol present in any sample, and a table showing the centesimal proportions of alcohol in various wines, will be found described under Alcoholometry.

Free acids, or acidulous salts, are present in most wines. Malic, tartaric, and citric are commonly met with. Port wine contains tannic acid, and the briskness of effervescent wines is due to carbonic acid. This natural acidity of wine must not be confounded with the sourness which wine sometimes acquires, and which is due to acetic acid, generated by oxidation of alcohol, as already described.

The *colouring matter* of wine is derived from the husk of the grape. If wine be prepared from the expressed juice only, it will have little or no colour, as in the case of Champagne; but if the skin be also present, its colour will go into solution during the process of fermentation, and will give the characteristic tint to the resulting wine. The presence or absence of the purple skin, therefore, and not the colour of the grape, as popularly supposed, determines the colour of wine.

The chief *saline constituent* of wine is bitartrate of potash, or *wine-stone*, or *argol*, as it is technically termed. It is the commercial source of tartaric acid, and has already been treated of in detail. [Tartaric Acid.]

Wines are much adulterated. For the English market they are commonly "fortified" with brandy, and superior varieties are frequently diluted with those of inferior quality. Elderberry juice, called Cheripigo, also the juice of *Phytolacea decandra*, boiled must, and burnt sugar are used for colouring; kino and logwood are used for the same purpose, and to augment the astringency of port wine; and occasionally artificial ethers are added to give flavour.

WINE MANUFACTURE. Wine is the result of the fermentation of certain saccharine fluids, either existing naturally in the juices of plants, or artificially blended together. The natural juices susceptible of fermentation are found either in the roots of plants, such as the parsnip and beet-root; extracted from the stem, as in the birch and cocoa-palm; expressed from the leaves, as in the grape-vine; obtained from the spatha, as of the *Sagus vinifera*, the *Phœnix dactylifera*, and other palms; and in the mature or immature fruits of many well-known plants, such as gooseberries, currants, and, above all, the grape, to the fermented juice of which the term wine is always understood to be applied when used absolutely. Though alcohol is present in all wines, yet many other principles exist in them; the number of which, and the manner in which they are blended together, as well as their relative proportion, give to different wines their distinctive properties.

The *Vitis vinifera*, the only species which yields the most esteemed wine, has, from receiving the long-continued attention and culture of man, a very extensive geographical range. [Vitis, in Nat. Hist. Div.] From 54° or almost 55° N. lat. to 45° S. lat., the vine may be found; but it by no means yields a grape fit for fermenting into a sound good wine in all the intermediate space. Up to the 51st degree of N. lat. the preparation of this beverage is conducted with various degrees of success and diversities in the qualities of the wines. In the hotter countries alone are the rich sweet wines, often called in technical language *Vins de Liqueurs*, prepared, as in those only is so much sugar present as to allow the fermentation to furnish sufficient of the vinous principles to the product, when the fermentation ceases from the leaven being all expended. The Muscat grape, which in the south of France yields the rich sweet wines termed Frontignan, Lunel, and Rivesaltes, on the Rhine only ripens sufficiently to furnish a grape for the table or dessert. Nor does the same latitude always permit the grape to acquire the perfection requisite for good wine. The isothermal lines and the degree of humidity, especially the clearness or cloudiness of the atmosphere, have more influence. Thus in France the beneficial cultivation of the vine scarcely extends on the western side higher than 48°, but the boundary-line mounts upwards towards the east till we find the most renowned of the Rhine wines produced between 50° and 51°. The longitude of Devonshire is nearly that of the province of Spain which yields the finest sherries; and it is not alone the difference of 14 degrees of latitude which unfits the south of England for ripening a grape suitable for wine, since that portion of the Rhine which lies between Coblenz and Düsseldorf, which produces good wine, has precisely the same latitude; but the greater humidity and cloudiness of the atmosphere in the south-west of England, by intercepting the sun's rays, prevent the full ripening of the grape; for the same reason, Holland scarcely produces grapes possessing sugar enough to yield wine (Mulder); and the observations of Dr. Daubeny have proved that the ripening of fruits depends more on the illuminating rays than on the calorific or chemical rays. The specious hopes held out by some writers that the grape might be cultivated in England so as to yield wine, would soon be dissipated by any extensive trials, which it is to be desired may never be made. (Barton's 'Lecture on the Geography of Plants;' and Watson, 'Geographical Distribution of British Plants.')

But different climates, though they may equally permit the grape to ripen, yet impress on it peculiarities easily distinguishable in the wines produced by the same kind of grape. Thus the Hock grapes yield a kind of wine possessed of distinct qualities when grown along the Main or Rhine; the same sort of grapes, grown near Lisbon, yield Bucellas, which only retains some of the peculiarities of the original; the same grapes at the Cape of Good Hope yield what is termed Cape Hock, scarcely bearing any resemblance to the true Rhenish; while the Sercial of Madeira, produced by the same sort of grapes, though a delicious wine, has scarcely a quality, except durability, like that of the original. Some local influences produce effects which are alike inexplicable and inimitable. These, though generally attributed to the soil, are not always or solely owing to its composition and qualities. In some instances the soil is the main cause of difference, as seen in the Constantia of the Cape. The climate there is most favourable to the growth of the vine, yet in one small space only is a tolerable wine produced, the two contiguous farms of the Great and Little Constantia yielding, the former the red sweet wine, the latter the white Constantia: the soil on which they grow is decomposed sandstone. Where no appreciable difference of soil can be pointed out, differences arise from the cultivation of a different kind of grape. It is stated, on the authority of Meyen ('Pflanzen-Geographie,' p. 369 of English translation, published by the Ray Society), that there are instances "of the same variety of vine being planted on the side of a hill or mountain, and the wine which is the produce of the grapes from the highest parts of the mountain will differ essentially from the wine which is the produce of the grapes of the lower part of the mountain. The wines known by the name of Johannisberger and Rudesheimer in Germany are the produce of vines growing close together, and resembling each other in external characters. The vineyards also that produce the Leistenwein, Würzburger, and Steinwein are very near to each other. It is probable that this difference is owing to the composition of the soil." This is not altogether correct. Johannisberg is only 150 feet above the level of the Rhine, and it is quite certain that the produce of the summit, close to the castle or Schloss of Johannisberg, is of a quality vastly superior to the produce of the place called Johannisbergerhöhl, not from any peculiar or insurmountable cause, but because the former, belonging to Prince Metternich (and the adjacent parts to some other large proprietors), can receive an amount of careful and skilful treatment, which the other, being divided among a number of small proprietors, never does. This subdivision is the cause of an annual loss of many thousands of pounds. (Bronner, 'Weinbau in Süd Deutschland, Dritte Heft,' p. 113.) The grape cultivated in both places is the little Riesling (*Der Kleine Riesling* of some, *Weisser Riesling* of others; the *Vitis vinifera pusilla* of Babo and Metzger's 'Wein und Tafeltrauben der Deutschen Weinberge und Gärten,' Heft viii, t. 46); but in the vineyard of Prince Metternich and the other great proprietors three gatherings of the grapes are made as they reach maturity, and other measures are adopted to ensure a produce of the highest excellence. Besides the protection of the castle wall, the whole has since 1824 been surrounded with a stone wall 10 feet high. This greatly promotes the steady progress to maturity of the grapes by securing a quiescent state of the air, which is known to be extremely beneficial, and which, when imitated on a small scale in this country by surrounding a bunch of grapes with a muslin bag, forwards its ripening very much. The wine of Luginsland and the Liebfrauenmilch owe their superiority over that of the neighbouring vineyards to the protection of the town-wall of Worms. (Bronner, Heft ii., pp. 18–20.) The advantage of protection against agitation of the air is so well understood in the Rheingau, that the belts of vineyards which clothe the height of Hochheim bring very different prices, according to their position. One morgen, close to the bed of the river Main, brings in the market two thousand florins; a higher morgen brings one thousand florins; and one at the summit only five hundred. (Bronner, iii., p. 14.) The geognostic character of the soil of Johannisberg is argillaceous schist, with a very moderate proportion of mica, and in one place passes into a reddish quartz, which is very hard, and undergoes but slowly any decomposition. This is overlaid with diluvial and alluvial deposits in most places except the south-west side. From these and other circumstances it follows that the soil is of a very diversified character. (Bronner, iii., p. 116.) The exposure is south-west, with a slope of from ten to fifteen degrees. Rudesheim is well protected by its natural position and a lofty forest called Niederwald: it is much steeper, so that the earth can be kept from being washed down only by numerous terraces, between which the air is as hot as in a conservatory. The soil is composed of stones of a dark colour, which radiate heat during the night to such a degree, that the grapes are surrounded by almost a southern climate. The grape most common, at least in the old vineyards, is the Orleans (*Vitis v. aureliana*, B. u. M., Heft x., t. 60), which has the property, in this stony and hot ground, of continuing productive until the age of fifty or more, which is not the case with any other grape. But as it only gives a good wine in very favourable years, and as the wine from the Riesling grape brings so high a price, the new vineyards are mostly planted with the Riesling: the propriety of this substitution is very doubtful. (Bronner, iii., 136.) These facts are sufficient to account for the differences between the Johannisberger and Rudesheimer wines.

The differences between Leistenwein and Steinwein are still more easily accounted for. The Leiste is on the left side of the river Main, the Stein on the right, the Stein being close to the river. The soil of both is argillaceous with calcareous portions, especially fragments of lime, and this is the soil commonly met with in Würtemberg and in all Franconia. Why these two wines should differ from all others of the district is unintelligible; but the difference between themselves is owing to the grapes. The vineyards of the Leiste (that is, the best portion, *gute Leiste*,) are planted in a great measure with the Riesling and Traminer (*V. v. tyrolensis*, B. u. M., Heft xii., t. 72), with about a third of the Elbling grape (*V. v. albuelis*, B. und M., Heft iii., t. 14); and in the other vineyards is the white Traminer, called *franken*, by some *gutedel* (*V. v. aminea*, B. u. M., Heft ii., t. 9), that is, both white and black. Besides these there occurs in considerable proportion the Hermitage grape, brought from France, which here succeeds well, retaining its fine aroma, though its natural site is granitic. The selection of the grapes, when ripe, is attended to with extraordinary care. (Bronner, vi., p. 82.) The predominant grape of the Stein vineyard is the Elbling, mixed with a few of the Riesling and other sorts. The Leistenwein is regarded as the second finest wine of the south of Germany. The Steinwein must not be confounded with the Steinberger wine of the Rhine. The Montillado of Spain is the produce of a white soil, containing 70 per cent. of carbonate of lime, with alumina, silica, and a little magnesia, while the Manzanilla is the produce of the terrains rouges et sablonneux. Yet the wines do not greatly differ in taste or flavour. More importance is attached to the soil than it deserves; its physical properties are of more importance than its chemical. Chaptal was clearly of this opinion, for he maintained that, provided it is porous, free, and light, its component parts are of little consequence. Perhaps calcareous is on the whole the best, simply because it readily imbibes the rain, and allows a clear atmosphere to surround the vines. Even Mr. Busby (see his 'Visit to the Principal Vineyards of France and Spain,' p. 131), who so strenuously maintains the superiority of a calcareous soil, when remarking on the reputation and limited extent of some of the first-rate vineyards, repudiates the idea of the soil being the cause. "In all those districts which produce wines of high reputation, some few individuals have seen the advantage of selecting a particular variety of grape, and of managing its culture so as to bring it to the highest state of perfection of which it is capable. The same care has been extended to the making and subsequent management of their wine, by seizing the most favourable moment for the vintage—by the rapidity with which the grapes are gathered and pressed, so that the whole contents of each vat may be in exactly the same state, and a simultaneous and equal fermentation be secured throughout—by exercising equal discrimination and care in the time and manner of drawing off the wine, and in its subsequent treatment in the vats or casks where it is kept; and lastly, by not selling the wine till it should have acquired all the perfection which it could acquire from age, and by selling, as the produce of their own vineyards, only such vintages as were calculated to acquire or maintain its celebrity. By these means have the vineyards of a few individuals acquired a reputation which has enabled the proprietors to command almost their own prices for their wines; and it was evidently the interest of such persons that the excellence of their wines should be imputed to a peculiarity in the soil, rather than to a system of management which others might imitate" (p. 133). But some experienced wine-factors, not proprietors of vineyards, hold a different opinion.

It is greatly to be wished that the truth of this important statement were impressed on all persons having the charge of vineyards, as it is certain that by attention to these and other circumstances quite within their control, the quantity of good wine might be much increased and its price lessened. Bronner distinctly states that in the Bergstrasse near Heidelberg, by obstinate adherence to old and indolent practices, the produce is annually one-third less than it might be (Heft vii., p. 20).

Where some peculiar strong-smelling substance exists in the soil, an odour is communicated to the wine which renders it unpleasant. This is the case when stinkstein (a native variety of subcarbonate of lime, called *pierre puante*) is present. The vine-growers of France and Portugal have so strong an aversion to manuring the vines, from the notion that it deteriorates the flavour of the wine, that in the latter country, at least in the port-yielding district of the Alto Douro, the use of manure is forbidden by law. This seems to be a prejudice, for the German cultivators manure the vines very freely, and no wines are more esteemed for *bouquet* than those of the Rhine; and Bronner justifies the practice (Heft iii. 44), not only with fresh cow-dung, which is used at Johannisberg, but with fragments of woollen cloth previously steeped in liquid manure and dried, which is found greatly to augment the produce. Professor Rau bears testimony to its utility. The practice is adopted oftener with the red than white grapes; the former every third or fourth year, the latter only every tenth. Even the proprietors of the vineyards near Bordeaux, which produce the highly-prized clarets, employ manure "once every four or five years." (Paguierre, 'Wines of Bordeaux,' p. 28.) But perhaps the best manure for vines is the cuttings of the vines themselves when pruned, as recommended in Liebig's 'Chemistry in its application to Agriculture,' 2nd edit., p. 250:—"The vines are pruned in the end of July or beginning of August, whilst still fresh and moist. If they are then cut into small pieces and mixed with the earth, they undergo putrefaction so completely, that at the end of four weeks not the smallest trace of them can be found." These restore to the soil the alkalies abstracted by the grapes, which are so necessary for the perfection of this fruit. Probably ferns, so rich in alkalies, would answer well. But the same vines will yield a wine having very different qualities, at least as to flavour and perfume, in different seasons. "These qualities are, in truth, of so delicate and inconstant a nature, that they may be said to vary from year to year; there being perhaps no two vintages, though collected from the same spot and managed in the same manner, that will be found completely identical in flavour and perfume." (Henderson's 'History of Ancient and Modern Wines,' p. 135.) The correctness of this statement is proved by the varying character of the vintages in different years. It rarely happens that the good Port years coincide with the good Claret years, as a heat which ripens well the grapes in the comparatively cold climate of Medoc scorches the grapes in the Alto Douro, and *vice versâ*. The year 1811, commonly called the comet year, was remarkable for the excellence of the vintage in almost all the wine-yielding countries of Europe.

The subject of the cultivation of the grape has been treated under VINEYARD; we proceed, therefore, to speak of the manufacture of wine. The stage at which the grape is fit for gathering depends upon the kind of wine intended to be made. When a brisk wine is wished, such as Champagne, the grapes are gathered before they are fully ripe; and they may be collected even in foggy weather, or before the dew is dissipated from the vines; though for all other kinds dry clear weather is proper. (Henderson, p. 15.) This author (in general so accurate) states that "if the object be to obtain a dry full-flavoured wine, the grapes should be gathered as soon as they have acquired their proper maturity, and before they begin to shrink or wither on the stalk." But in the case of the most esteemed German wines, which are the *driest* of all, the gathering of the grape is postponed as late as possible, by which many free acids are got rid of, and the wine at a much earlier period of keeping is so soft and delicate, that the new wines are preferred to the extremely old wines, which were in great request previous to the adoption of the plan of late gathering. The advantage of this was first accidentally discovered at Johannisberg in 1790; but it was so long opposed that its establishment as a practice dates only from 1822. (Bronner, Heft iii., pp. 149-150.) But frost, in November, 1858, destroyed to some extent the vintage of 1858. Thus at Johannisberg the vintage of 1811 was very late; that of 1831 did not commence till the 17th October, nor did it conclude till the 5th November: and in 1834 the grapes were all hanging on the vines, but perfectly sound, so late as November. Yet these are among the most renowned vintages of the present century. In the warmer parts of the south of Spain and of France, and also at Tokay, where vins de liqueurs are made, the grapes are allowed to remain very long on the vines; the stalks are twisted, so as to prevent the influx of any recent sap; the thinner or watery portion evaporates, and the dry or shrivelled grape almost resembles a raisin, and contains much sugar. On the Rhône a small quantity of sweet wine is made from the ripest grapes, which are hung up on hurdles, or spread on straw, for six or eight weeks, or until they become half dried. The liquor obtained from them, from the mode of preparation, receives the name of *straw wine* (*vin de paille*). In some cases the must is boiled; this is often done with the sherries of Spain: when the boiling is carried far, a very sweet luscious wine is produced, such as the wine of Cyprus, the *vino cotto* of the Italians (*vinum coctum* of the ancients), the original Malmseys of Candia, and the other rich wines of the Grecian archipelago. The colour of wine is not always dependent on the colour of the grape from which it is prepared. Champagne is the produce of a red grape: red and white grapes are used indiscriminately for Sherry; but white Port is made only from a white grape. The stalks promote the fermentation, and if they, as well as the hulls or skins, are withdrawn before the fermentation has proceeded far, as it is not till some alcohol is generated that the colouring principle is dissolved, those even of red grapes neither communicate colour nor taste to the wine. They are early withdrawn from the delicate red wines of Bordeaux; but retained longer in the red wines of Portugal; hence the greater austerity and astringency of the latter. The wine of Cahors, prepared from a grape called *Auxerrois*, or *pied de perdrix*, yields a wine almost black, the colour being deepened by an admixture of a preparation called *raugome*, which is merely a portion of the must of this grape, boiled for a few minutes with the strongest spirit of wine, in the proportion of one part of spirit to four of must, added to it. This extracts the colouring principle most thoroughly; and communicates not only to the wine of Cahors, but also to many of the Bordeaux wines, to which raugome is frequently added, a deep hue. "The more this preparation is required and added, the less the wine will bear keeping." (Paguierre, p. 112.)

Tabular View of the Vintages of Four of the most different and celebrated Wine-countries, extending from almost the most western to the most eastern points where famous Wines are produced in Europe. In the column of Clarets only the most noted years are given, the intermediate ones being either "null," "bad," or only "middling." The expression "good" refers only to the quality: some years being good, with an abundant produce; others good, while the quantity was small.

Year.	Port.	Claret.	Rhenish.	Tokay.
1811	good	first-rate	very good	very good
1812	fine	..	middling	good
1813	middling	..	bad	bad
1814	middling	..	bad	bad
1815	very fine	first-rate	middling	bad
1816	middling	..	very bad	bad
1817	middling	..	very bad	middling
1818	very bad	..	middling	middling
1819	bad	good	good	middling
1820	very fine	..	inferior	bad
1821	fine	..	inferior	middling
1822	fine	..	very good	good
1823	fairish	..	inferior	good
1824	inferior	..	inferior	middling
1825	bad	very good	middling	bad
1826	middling	..	good	middling
1827	fine	..	good	good
1828	middling	..	inferior	bad
1829	bad	..	bad	bad
1830	fine	..	bad	good
1831	inferior	..	good	middling
1832	inferior	..	inferior	..
1833	middling	..	inferior	..
1834	very fine	good	very good	..
1835	middling	..	inferior	..
1836	inferior	..	inferior	..
1837	inferior	..	bad	..
1838	inferior	..	bad	..
1839	bad	..	bad	..
1840	very fine	..	bad	..
1841	bad	..	bad	..
1842	fine	..	middling	..
1843	inferior	..	bad	..
1844	fine	very good	bad	..
1845	bad	..	bad	..
1846	good	..	very good	..
1847	very fine	very good	bad	..
1848	middling	very good	good !	..
1849	inferior	..	bad	..
1850	good	..	bad	..
1851	good	good	bad	..
1852	bad	..	middling	..
1853	fine	..	bad	..
1854	good	very good	bad	..
1855	bad	..	middling	..
1856	very bad	..	bad	..
1857	very bad	good	very good	..
1858	good	very good	very good	..
1859	bad	..	good	..
1860	good	..	very bad	..

The wines of the Moselle may be distinguished from those of the Rhine by having a greenish colour, while the latter have a yellowish colour. At Cotnar, in Moldavia, a wine is prepared which is green, and which becomes deeper by time; while the strength increases so much, that if the wine be kept in a deep and well-vaulted cellar, in three or four years it almost resembles brandy, but without so readily affecting the head. "On exposing red wines in bottles to the action of the sun's rays the colouring-matter separates in large flakes, without altering the flavour of the wine." (Henderson.) Sulphurous acid ought not to be used for fuming the casks into which red wine is to be put, as it destroys their colour. Spirit of wine should be used to rinse such casks. The colour of wine is judged of by placing some of it in a small silver tray or saucer (called in Portuguese *tambuladeira*) slightly raised in the centre; the colour it exhibits as it passes over the convex centre when agitated, is that which guides the broker.

To proceed with the steps towards the conversion of the must into wine. "Before beginning the vintage it is necessary to be assured that the fruit which is to be gathered has attained the proper and necessary maturity, for on this almost always depends, in a great measure, the quality of the wine. The cultivator is liable to fall into one of two errors, which, though very different and opposite to each other, are not less hurtful to the wine, especially to the red, which is more delicate and susceptible of injury in making than the white. If gathered too soon, and before the grape has attained to the fit degree of maturity, the wine is likely to be raw (*vert*), which is the greatest fault it can have, and the most difficult to correct; the wines having this defect becoming generally hard when old. The other error, though of less consequence, is leaving the grapes till they are too ripe, which may then rot before gathered." (In the north of France this is more liable to occur; in the south, less so: at Langoe, between Bordeaux and Toulouse, a white sweet wine is prepared from spoiled grapes.) "The wine made from grapes too ripe acquires a sweetish taste, which causes it to work a long while in the barrels, and renders it sour and difficult to keep. The wine attacked by this vice requires greater care than any other; for if neglected ever so little, either in racking or filling, it easily becomes sour. However, it is better to gather late than too soon." (Paguierre, p. 47.) At Tokay, where the grapes are allowed to hang on the vines till some of them lose their globular shape and transparency (*trockenbeeren*), the gatherers put these into a separate basket; and the juice which exudes from them simply by the pressure of one above the other is carefully collected, and known under the name of *Tokayer-essenz*. This thick syrupy liquid does not ferment, and always remains thick and muddy. It is not an article of commerce, as the cultivators keep it to add to the finest wine (called *Ausbruch*) either at the beginning of the fermentation or at the termination. The former is the preferable mode.

We may take Clarets as an illustration of the process of manufacturing: that being one of the most carefully prepared kinds of wine, it will serve as an example of all. In the words of Paguierre ('Wines of Bordeaux'), "the proprietors of the vineyards, and especially of the first growths, after having prepared the wine-vessels, gather the grapes together and pick them, that is, set aside all the bunches which are rotten, those which do not seem quite ripe, or which are withered, and, finally, all which might hurt the quality of the wine. Their first care then is to make a principal vat of the best fruit, which is called the mother-cask (*cuve-mère*), into which, after picking, they put the first and best grapes which arrive, without their stalks, and without treading them, till they are from fifteen to twenty inches deep; after which they throw about two gallons of old Cognac or Armagnac upon them, and then another bed of picked grapes, followed by two gallons more of brandy, and so on till the vat is full. When full they add spirit of wine, taking for proportion about four gallons of spirits of wine for a wine-vat of from thirty to thirty-six tuns. It must be observed that the quantity of brandy or spirits of wine depends on the quality of the vintage; for if bad, more must be put in order to excite fermentation, and replace what it wants by defect of maturity. (Of late it has become customary to add starch-sugar when the grapes are deficient in saccharine principles.) Raisins are often used for the inferior German wines. (Mulder, p. 51, English Translation.) The *cuve-mère* being filled, it is shut hermetically, and is well covered with blankets, in order that the air may not penetrate. This vat is left in this state for three weeks or a month without being touched. A small brass cock is put into the side of the vat, at about the height of the third of its depth from the bottom, in order to be able to judge at will of the progress of the fermentation, and to know the moment when, the ebullition having subsided, it may be racked off and put into casks, prepared beforehand by scalding and rinsing with a little spirits of wine. It is known that the liquor is fit to be drawn off when it has become cool and is sufficiently clear. While the *cuve-mère* is at work, the vintage is continued in the usual manner; that is, as the grapes are brought in and picked, they are trodden in the press, and put with their stalks into the vats, where the fermentation takes place naturally. These vessels are not entirely filled; about one foot or fifteen inches are left for the fermentation, which sometimes overflows, especially when the vintage has attained perfect maturity. They call *chapeau* the stalks, seeds, and skins, &c., which float on the surface of the wine. The vintage being finished, and the vats lightly covered, they are left to ferment, taking care to visit them twice a day. To rack them it is necessary to wait till they are quite cold, which is from eight to twelve days. From the moment that the cask has become sufficiently cool, it is necessary to draw it off; for if you leave the wine upon the lees (*marre*), or with its crust (*chapeau*), it would take the taste of the stalks, which is very disagreeable and difficult to get rid of, and is a great defect. If the cask be racked off too soon, the fermentation would not be complete, and the wine would run the risk of working too much in the barrel, and of not keeping. When the vats are found to be in a proper state for racking, the wine is drawn off into barrels prepared for the purpose, which are filled about two-thirds or three-fourths; after which the *cuve-mère* is emptied, and the wine is poured in equal portions into these casks so as to fill them; and the remainder is employed to fill up, every six or eight days, what is consumed by evaporation, or what the casks have ullaged. All proprietors have not the means or localities to make a *cuve-mère* by means of old brandy or spirits of wine, either because their vintage is not sufficiently extensive, or because they do not possess the things necessary for its execution. But the fermentation succeeds much better in large vessels, especially when prepared as above, than in the lesser ones used by small proprietors. The casks, being full, are left about eight days without being bunged; care, however, is taken for the time to cover the bung-hole with a stone, brick, or piece of wood. They are filled up every two days, and when bunged, every eight days at least, till the wine is in a state to allow the cask to be kept with the bung-hole at the side, which is not till after eighteen months.

Manner of making White Wine.—To make the white wine it is not, like the red, put into the vat to ferment, but the grapes are trod, and when taken from the press, the juice, skins, and seeds are put into casks (the stalks having been separated); here it ferments and becomes wine of itself. When the fermentation in the barrels has entirely ceased, it is racked off, and care is taken to fill up what has been consumed by evaporation, as often as possible, and this operation ought to take place at least once or twice a week.

The wine, if it has succeeded, ought to be clear, transparent, of a fine soft colour, a lively smell, and a balsamic taste, slightly piquant, but agreeable, inclining to that of the raspberry, violet, or mignonette, filling the mouth, and passing without irritating the throat, giving a gentle heat to the stomach and not getting too quickly into the head.

It is necessary to know what is meant by the *flavour* of wine, and what by *bouquet*, terms often confounded. The flavour, called by the French *sève*, indicates the vinous power and aromatic savour which are felt in the act of swallowing the wine, embalming the mouth, and continuing to be felt after the passage of the liquor. It seems to consist of the impression made by the alcohol and the aromatic particles which are liberated and volatilised as soon as the wine receives the warmth of the mouth and stomach. The *sève* differs from the *bouquet*, inasmuch as the latter declares itself the moment the wine is exposed to the air; it is no criterion of the vinous force or quantity of alcohol present (being in fact greatest in the weak wines), and influences the organ of smell rather than of taste. In the red wines of Medoc and the Graves, the *sève* and *bouquet* exist only in the old wines: these qualities cannot be known, but only conjectured in the new wines; and experience has alone taught the brokers, that when wines of particular growths present themselves without harshness (*verdeur*), with colour, body, and vinosity, they will, when old, acquire a balsamic flavour (*sève*) and mellowness (*moëlleux*), besides the colour and body; they will also keep well, which constitutes the perfection of wine. To give bouquet to the wine, two drachms of orris (the rhizoma of the *Iris florentina*) in powder are put into a fine bag of muslin, and hung for about fifteen days in the cask. Many persons, to make the wine appear older and higher flavoured, and at the same time to prevent injuring its quality, employ raspberry brandy. The bouquet which by these means is given to the common or ordinary wines never replaces perfectly the natural flavour of the choice wines of Medoc and Graves. It is very easy to distinguish the fictitious bouquet by even moderate experience in tasting wine. The bouquet is altogether a new product, and is in no way dependent on the perfume of the grape from which the wine is made. Red wines scarcely ever retain a trace of the odour of the grapes; the white muscadine wines do in some degree, especially Frontignan. It has been recommended to suspend some of the ripest and most odoriferous bunches of the grapes in the cask after the first fermentation has subsided, in order to heighten the perfume of the wine, a practice long pursued in the *vini raspati* of the Italians, and *vins rapés* of the French. But if the *œnanthic acid* and *œnanthic ether*, on which the bouquet depends, be the consequence of a true process of putrefaction (somewhat similar to what occurs in musk, by which the odour is evolved), by a mutual interchange of the elements of gluten and sugar, this process cannot accomplish the object, and only runs the risk of exciting a hurtful fermentation. The best account of the bouquet of wine is given by Liebig, who, with Pélouze, discovered œnanthic ether:—"It is well known that wine and fermented liquors generally contain, in addition to alcohol, other substances which could not be detected before their fermentation, and which must have been formed, therefore, during that process. The smell and taste which distinguish wine from all other fermented liquids are known to depend upon an ether of a volatile and highly combustible acid, which is of an oily nature, and to which the name of œnanthic ether has been given . . . The substances in wine to which its taste and smell are owing, are generated during the fermentation of the juice of such grapes as contain a certain quantity of tartaric acid; they are not found in wines which are free from all acid, or which contain a different organic acid, such as acetic acid. The wines of warm climates possess no odour; wines grown in France have it in a marked degree; but in the wines from the Rhine the perfume is most intense. The kinds of grapes on the Rhine which ripen very late, and scarcely ever completely, such as the *Riesling* and *Orleans*, have the strongest perfume or bouquet, and contain proportionally a larger quantity of tartaric acid. The earlier grapes, such as the *Ruländer* and others, contain a large proportion of alcohol, and are similar to Spanish wines in their flavour, but they possess no bouquet . . . . The acid of wines, and their characteristic perfumes, have some connection, for they are always found together; and it can scarcely be doubted that the presence of the former exercises a certain influence on the formation of the latter. Whatever opinion may be held regarding the origin of the volatile odoriferous substances obtained in the fermentation of wine, it is quite certain that the characteristic smell of wine is owing to an ether of an organic acid, resembling one of the fatty acids . . . On the Rhine, an artificial bouquet is often given to wine for fraudulent purposes, by the addition of several species of the sage and rue to the fermenting liquid; but the perfume thus obtained differs from the genuine aroma by its inferior durability, it being gradually dissipated." (Liebig's 'Organic Chemistry.')

The fermentation is more prompt and lively in proportion to the quantity of must; hence the best wine is made when a large quantity of must is operated on. In some cases, when the season is cold and the grapes are imperfectly ripened, it is necessary to promote the fermentation by artificial means; either adding some boiling must, or withdrawing some of the excess of water by adding baked gypsum. The fermentation is best carried on in covered vats: since in open ones not only the carbonic acid gas escapes, by which the wine is rendered flatter, but much of the alcohol and aroma are lost, and the wine rendered weak. The length of time that the fermentation is continued in the large vats depends on the kind of wine intended to be made. The temperature also influences its progress and the results.

In the Champagne country, the grapes which are to fill one *cuve* are all pressed within the space of two hours, and the must allowed to remain in the *cuve* for a period varying from six or twelve to eighteen hours, according to the temperature, during which it undergoes a process of spontaneous purification, becoming as clear as water. The moment when this is complete is watched for with the utmost care; it is then drawn off into small casks, which are well sulphured (a process which is hereafter explained), and put into cellars below ground, the bunghole being left open, but covered with a flint stone. The overflowing froth, or yeast, is removed from time to time till December or January, when the chief purchases are made, as then the wine can be tasted and proved. It is then also submitted to the process of *fining*.

At Tokay the must is allowed to remain in the vat from twenty-four to thirty-six hours, till the first signs of fermentation are manifested; it is then drawn off into small casks (which are never sulphured) and placed in a still part of the cellar. The effervescence lasts two or three months.

The fermentation spoken of hitherto is called the primary or active fermentation; but there is a subsequent one, called the secondary or insensible, which, though obviously a continuation of the former, is less attended to, but yet of great importance as relates to the ripening, keeping, and acidity of the wine. A knowledge of the causes of fermentation, and the conditions under which it can take place, is essential to the comprehension of the measures necessary for ripening the wine and preserving it in perfection. The subject has been fully explained in Liebig's 'Chemistry of Agriculture,' and Mulder's 'Chemistry of Wine,' London, 1859.

When a *dry* wine is wished, it is necessary that all the sugar should be transformed into alcohol. To do this the fermentation is excited from time to time, by *rolling* the wine, or returning it to the lees to *feed*. As the wine contains variable quantities of undecomposed gluten in solution or thrown down to the bottom of the cask, it is only necessary to stir up the lees to re-excite the fermentation. But lest the point should be passed at which the vinous fermentation is nearly complete, and the acetous would begin, all the undecomposed ferment is removed. Much of it remains in the vat in which the first and violent fermentation takes place; when the fermenting liquid is put in casks, these are generally kept nearly full, by frequent additions of fresh juice, so that much of the ferment works out at the bung-hole, which is seldom perfectly closed for two or three months. Racking is practised, for valuable wines, as often as three times the first year. This consists in transferring the wine to a fresh cask. It is in doing this that the practice of *sulphuring* is mostly adopted. It consists in burning sulphur-matches or linen steeped in sulphur in the cask previously well rinsed, by which all the oxygen of the atmospheric air is consumed, and a quantity of sulphurous acid gas produced. This must be carefully done, as, if in excess, the wine acquires the taste of sulphur, which it would keep for some time. White wines require most sulphur, especially when very *dry*. It is proper to transfer the wine immediately to the exhausted cask, otherwise it would speedily get filled again with common atmospheric air. Dr. M'Culloch recommends the following method, as he remarks that by the common method of tapping it is scarcely possible to draw the wine without mixing a portion of the lees with it:—"To effect it, a cock is introduced into the full cask at the usual place of tapping, three or four inches above its bottom, from which a leather hose (a flexible caoutchouc tube would be better) pipe passes into the bung-hole of the empty one. A common pair of bellows may then be so fitted to the bung-hole of the full cask as to force by its action the whole of the clear liquor through the hose into the empty vessel. By this means the least possible disturbance is created, and the wine is at the same time preserved from the injurious contact of atmospheric air." The whole of the wine should not be drawn off, as the *cap* frequently contains principles which would readily re-excite fermentation. What is left may be employed to form either brandy or vinegar, according to its kind or value. Another means may be used, instead of sulphuring, to preventing the acetous fermentation, namely, the use of *sulphite of potash*. A drachm is in general sufficient for a pipe of wine, and it communicates no taste. The utility of both agents consists in absorbing any trace of oxygen, and preventing it acting on the organic substance. Many volatile oils have the power of checking the vinous fermentation, but their odour is a practical obstacle to their employment. They probably act by hindering the development of the fungus (*Saccharomyces vini*). Alkalies, combining with the free acids, the presence of which is so essential to the process of fermentation, also hinder it, but as they are destructive of the qualities of the wine, they are inadmissible. Black oxide of manganese, though recommended by Dr. M'Culloch, should never be used for wine where sulphuring has been employed, as it would most readily give off oxygen. Racking can only free the wine from matters which are insoluble, and either deposited among the lees or floating on the surface. In order to get rid of some other matters held in solution, a different practice is adopted. This constitutes the process of *fining*. Isinglass in solution in wine, or white of eggs, is commonly employed for this purpose. The common and new wines require more isinglass than the fine and old ones. If the wines have been deprived of the tannin extracted from the seeds of the grape, isinglass has no influence in purifying them. If kept in oak casks, however, as is always the rule in France, they extract tannin from their sides. Numerous powders and compounds, as well as other expedients for keeping or improving wines, are detailed in Jullien, 'Manual du Sommelier.' The process of fining is always repeated previous to bottling the wine.

At Bordeaux the white wines are generally ready for the first racking in December, the red not till March; the second racking is to prevent the working which the great heats of July and August might occasion in them; and the third in October, before the cold comes on. A favourable state of the weather must be chosen for these processes. A fourth racking takes place in eighteen months after the vintage, in March; it is then that the casks may be stowed with the bung at the side. After this it only requires to be racked twice a year, in March and October. When it has attained the age of five or six years, it requires racking only once a year, which is always done in March, the moment when the wines are always finer and clearer than at any other season of the year.

One of the qualities of a good wine is firmness or durability; but in this respect there is great difference among wines, and one possessing every other requisite may be deficient in this essential. This may be imparted to it, however, by adding some other stronger wine, or one little disposed to undergo any deleterious change. Hence has arisen the practice of *mixing* wines, or, as it may be termed, their medication, vulgarly called *doctoring*, which being a judicious and honourable proceeding when the only articles employed are the real produce of the grape, is not to be confounded with unwholesome mixtures and dishonest practices, which deserve to be reprobated. Thus some of the *finest growths* of the Claret country require to be supported by the addition of Hermitage. It is obvious that no fraud is here contemplated, since the Hermitage is, perhaps, the more expensive wine of the two, and the maker can afford to add it only to the *best claret*. It in no degree impairs the fine characteristics of the choicest claret, nor diminishes the lightness for which first-rate claret is remarkable. Where *working* the wines is practised to fit them for the depraved taste of the majority of consumers in England, who are accustomed to the stronger wines of Spain and Portugal, the case is very different; and to the second and third growths the red wines of Roussillon, Bene Carlo from Spain, and brandy are added—to the detriment of the character of Claret. The latter addition is made under the pretext that it is necessary to enable the wine to bear the voyage. This, except so far as a very small quantity of brandy is concerned, is altogether erroneous, not only as relates to Claret, but also to Port and Sherry. The wines of Basseins and St. Eulalie-d'Ambares, two parishes near Bordeaux, furnish a wine which is generally purchased for the French navy, because it keeps well, and improves greatly at sea. The French wine-brokers at Bordeaux, familiar with the qualities of the first growths, and jealous for the reputation of their country, deplore the deterioration which much of their wines undergo to fit them for the English market. Still Claret with no other addition than Hermitage may be obtained here, provided a proper price is given, by resorting to wine-merchants of high repute. Two Sherries come to England devoid of brandy, *Amontillado* and *Manzanilla*; and it is now the wish of Port-wine merchants, of the highest character for science and probity, to introduce Port-wine with as small an admixture of brandy as possible, thereby consulting the health as well as palate of their customers. Brandy added after the early stages of fermentation is only mingled, not incorporated with, the wine — increasing its spirituosity, but not its vinosity, and producing on the human stomach, liver, and other organs the same effect as brandy merely diluted with an equivalent quantity of water. The extension therefore of a taste for the pure and unsophisticated wines in this country would be a national benefit. Sometimes the object in mixing wines is to produce a compound having a different or more agreeable quality than either of the wines singly possesses: hence the mixing of the Rhine-wines almost constitutes a science. Of all wines Sherry is the most mixed with the vintages of different years. "The wine-merchants of Xeres never exhaust their stock of finest and oldest wine. According to the price at which the wine expedited to the market is intended to be sold, it contains a larger or smaller proportion of old wine. But it is only in wines of a very high price that even a small portion of their finest wines is mixed. What is withdrawn from the oldest and finest casks is made up from the casks which approach them nearest in age and quality, and these are again replenished from the next in age and quality to them. Thus a cask of wine, said to be fifty years old, may contain a portion of the vintages of thirty or forty seasons." (Busby.) A sherry, the unmixed produce of one vintage, may now and then by a rare chance be obtained.

"It generally happens that when two distinct wines are mixed, the process of fermentation is partially renewed, or the mixture, in technical language, *frets*. This observation has led to a valuable practice in this manipulation, namely, *fretting-in*, technically so called. It is found by experience that mixed wines unite into one durable and homogeneous liquor only in consequence of this fermentation. A season and circumstances are therefore chosen, in which one or both of the wines to be thus mixed are either in a state of renewed fermentation or show a tendency to it." (McCulloch.) When wine is thus far made, it is left in the cask, or as it is termed, in the *wood*, to mature. The length of time required for this differs much in the different wines. It is the modern practice to send several wines either on voyages to warm climates or even leave them there for years. This is particularly the case with Sherry and Madeira; the fine qualities of the latter wine are very greatly developed by a few years' sojourn at Madras. Considerable evaporation, as well as ullage, occurs during this time; but it is remarkable that during the first years that the wine remains in the cask the watery particles chiefly evaporate, so that the wine gains in alcoholic strength, as well as flavour. Afterwards the alcohol begins to evaporate; and it is probable that at the period when the wines begin to lose alcohol they cease to improve in flavour. They are then fit to be bottled. The amount of evaporation varies with the climate, and the kind of wood of which the cask consists. In some cases it is as much as one-twelfth per cent. per aunum—especially if the cask is of Spanish chestnut, which is a most objectionable wood from the taste it imparts. Memel or Danzig oak is exclusively used for the finer Port wines; American oak is cheaper, but not so good. The presence of two staves of chestnut in each cask has been known to impart a taste, slight at first, but at last so marked as to lead to the rejection of the wine. The ullage is greatest in new casks; and hence old ones, when clean and sound, are preferred. But large casks of glass are now proposed: in these ullage is impossible.

During the stay of the wine in the wood, a deposit of tartar and other substances occurs. The colour undergoes a change, especially of the red wines; which is not similar in all. Thus while Port wines become lighter, those of Medoc become deeper: hence, to give the appearance of age to Port wines, *white* Port is added; but to Clarets the black wine of Cahors is added. The wine is thought to ripen better in large than small casks: this led to the construction of the enormous tuns of Heidelberg. Where any of the wine is drawn off, it is necessary to fill up the void as speedily as possible with wine nearly of the same quality, otherwise the air causes the remainder to become sour. Where wine is not to be had, the introduction of a quantity of olive oil protects the wine. A fungus is very apt to stretch across the surface of the wine, if one or other of these precautions is neglected. While in the vaults or cellars, the casks are likely to become affected with the *dry-rot*, by which much fine wine may be lost, especially if the cellars be damp. To guard against this, the casks should be carefully inspected from time to time. Cellars and vaults should be as remote as possible from streets and other ways by which waggons pass, the vibration caused by these often disturbing the more delicate wines. When wines have been kept in the wood for the period which experience has fixed as that proper for attaining maturity, they are generally put into bottles or flasks. In these some further change goes on, by which they are still further ameliorated. In many red wines a deposit occurs, forming a crust on the lower side of the bottle. The operation of bottling should take place in fine weather, if possible in March or October. Before this is done the wine must be fined, either with white of eggs, very fresh, or isinglass; after which the cask must be left to repose ten or fifteen days, according to the weather. The bottles must be perfectly clean, and if not new, care must be taken that no lead-drops remain in them, as these spoil the wine and render it deleterious. The corks should be perfectly sound, and as elastic as possible, so that when driven home they may expand beyond the contracted part of the neck of the bottle, and thoroughly exclude the air. To assist in this object, as well as to protect the corks from insects, the mouth of the bottle is often dipped in melted wax. As Champagne is bottled after remaining at longest only three years in the cask, considerable deposit takes place in the bottle. When recorked this is got rid of by the process of *dégorgement*. The bottle is inclined, the mouth downwards, till all the sediment is lodged in the neck; the cork is withdrawn, some of the wine rushes out, carrying before it the lees; the escape of the rest is hindered by an adroit adaptation of the fore-finger. To fill up the void caused by the wine which has escaped, a solution of sugar-candy in any of the common red wines of the country is added: the permanent cork, or the caoutchouc stopper, is now introduced; when the latter, a simple but convenient piece of mechanism is used: it is then wired down, and occasionally covered with tin-foil. If preserved in a cool cellar, good Champagne may be kept in perfection from ten to twenty years. In the great stores at Rheims the breakage amounts on an average to ten per cent. The Italian wines often have only olive-oil poured into the neck of the bottle, without using a cork.

Wines are classified according to the predominance of certain ingredients. When much alcohol is present, they are termed *strong* or *generous;* when otherwise, *light* or *weak;* when much sugar undecomposed, *sweet* or *luscious* (vins de liqueur); when little, *dry;* if a free acid in considerable proportion be present, they are called *acid* or *acescent;* when much carbonic acid is present, then *sparkling* or *effervescing* (*mousseux* of the French, *schaumwein*, German). Water is more abundant in wines made in wet seasons, and in the wine from new vineyards or young vines. These are also most prone to become sour. With the ancients it was a great object to get rid of the watery portion, for which purpose they employed various expedients, and often rendered them as thick as tar. The plan now adopted is best, to add starch-sugar to the must. The alcohol present in wines exists from an early stage of the fermentation, and is not a product of distillation. The quantity, according to Christison, varies from 16 per cent. in inferior Rudesheimer, to 37 per cent. in the strongest Port and Madeira; this being the per centage of proof-spirit estimated by volume. The condition in which alcohol exists as the natural product of the primary and secondary fermentation of the grape is very different from that in which it is found when obtained by distillation, even of wine, as in the case of the finest French brandy. The addition of any distilled spirit to wine is always to be reprobated, as it destroys the finer qualities of the wine, making it flat and mawkish. "The first and most conspicuous effect is the loss of that undefinable lively or brisk flavour which all those who possess accuracy of taste can discover in French wines or in natural wines; and a flatness, which must be sensible, by the principle of contrast, to the dullest palate which shall compare the taste of Claret with that of Port, or that of Hock or Grave with Lisbon or Bucellas" (Dr. M'Culloch). It tends equally, although in a greater length of time, to destroy the union of the colouring principle, which is well known to be deposited in Port wines, and apparently in a great measure from the action of this foreign substance. This fact explains why dishonest wine-merchants add brandy to their Port wines, to give them earlier the appearance of age, by producing the *crust*, a criterion by which no experienced or intelligent wine-drinker allows himself to be misled. Moreover no quantity of brandy can hinder the process of acetification, if the circumstances favourable to it are present. The pure light wines of France and Germany produce an agreeable exhilaration of mind, very unlike the mere physical excitement which results from the largely brandied wines, which are too much in vogue in England. The diseases also which attend spirit-drinkers, chiefly disorders of the liver, are commonly met with among the consumers of wines to which brandy or whiskey has been adventitiously added, though such disorders rarely if ever follow even the intemperate use of pure wine. Intoxication is a very rare occurrence among the inhabitants of the wine-producing countries. *Acid* is another component in wine. A free acid is necessary for the development of the fungus with which the progress of fermentation seems closely connected, for the evolution of the bouquet, for the agreeableness of the wine, and probably for its wholesomeness. In the best Rhine wines it is about ½ per cent. It is, therefore a popular error to denounce the acidity of wine. The kind of acid present is however a very important point. Tartaric acid is the best. Whether malic acid be ever present in good pure wine is doubtful, except in red Bordeaux, in which no lactic acid is found. (Mulder.) Racemic, silicic, and, perhaps, formic and glucic acid, may be found in some wines. (Mulder.) It is said to prevail in wines made in wet seasons. Citric acid is perhaps found in wine made from unripe grapes. It is not certain that oxalic acid is ever found in wine. It may be formed in some rare instances. It is very likely, however, to exist in considerable quantity in the spurious wine now largely made from the garden rhubarb. On many persons it must have a very hurtful effect. Acetic acid, or vinegar, is that which mostly abounds in low poor wines, especially of northern countries, and in good wines which have been mismanaged and allowed to spoil. The flat taste of the fluid and a smell of vinegar declare its presence. When wine is drunk on draught or from tap, it is most apt to form acid, unless the consumption be rapid. It is to disguise its presence that one of the most dangerous practices is adopted by vintners, namely adding sugar of lead to the tainted liquid. When this is suspected to have been used, sulphuretted hydrogen will reveal its presence. Sometimes it is present in bottled wine from a leaden shot being left in the bottle. A small iron chain is safest and best for cleaning bottles. Carbonic acid not only renders the wine sparkling, but increases its exhilarating action, as felt in Champagne. Tannic acid is present in Port and Tent, to the former of which it imparts both roughness and astringency. Port, both red and white, has less free acid than some of the finest Sherries. In the German wines Berzelius states that there exists tartrate of alumina and potass. Bitartrate of potass is more common. It is precipitated along with the colouring matter, and termed argol, found in wine-casks.

Respecting the relative amount of acidity in different wines much error prevails, not only in the popular mind, but among medical men. Dr. Prout ('On Stomach and Renal Diseases,' 4th edit., p. 8) affirms that sound Sherry contains less acid and sugar than any other wine. But several very careful experiments on different wines by no means confirm this statement. If applied to Manzanilla, which is the favourite wine of the Spaniards, it is true; but that wine is scarcely known in this country, however well it deserves to be so, as its freedom from adventitious brandy and from much acidity, with its slight degree of bitterness, a quality always to be prized in wine, strongly recommend it as a summer wine. It will be found that Port wine, both red and white, has less free acid than even some of the finest Sherries, though this is not confirmed by Dr. Jones' Appendix to Mülder. Madeira has long laboured under a most unjust opprobrium in this respect. That bad Madeira, and the wine which, though produced elsewhere, was sold for it, contain much acid, and readily disagreed with the stomach, may be perfectly true; but genuine first-rate Madeira has certainly very little, especially after a voyage to the East Indies. "The Madeira wines had fallen off in quality from over-shipment, and thereby gave further effect to this taste for Sherry. In this a useful lesson was given to all wine-growing countries." The observations of Dr. Paris are too just to be omitted:—"What, for instance, is the acid contained in Madeira, and against which so many mighty objections have been urged?—An atom merely of tartar! And yet the person who fancies that his digestion can be deranged by its action, will swallow twenty times the quantity of the same ingredient in some other shape, with perfect indifference and impunity." "Before we quit," says the same author, "the subject of vinous acidity, I shall beg to say a few words upon its supposed influence in exciting paroxysms of gout. That such attacks have followed particular potations, I do not mean to deny; but a slight excess of any kind, whether in diet or exercise, will excite the disease in those predisposed to it. Where the train is laid, an additional glass of Claret may have acted as the match; but in all such cases the explosion would have equally taken place had, instead of Claret, some other exciting cause fired it" ('On Diet,' p. 198). Liebig unhesitatingly affirms that, while to the free acid the exquisite *bouquet* of the Rhine wines is owing, to the tartar present in them some of their most salutary properties belong. To this he attributes the immunity enjoyed by those on the Rhine and Moselle, indeed of all who use the German wines, from the uric acid diathesis. This statement of the utility of these wines might be suspected to originate in national partiality; but it is abundantly confirmed by Dr. Prout and many others who have attended to the subject, and who have investigated it free from prejudice or favour. An occasional use of them is objectionable, but the habitual use is most salutary. (See Prout, 4th edit., p. 210.) Being light, they can be drunk without dilution, which is preferable to reducing a strong wine by adding water, which is much more prone to produce acidity in the stomach. (Prout, p. 9.) The water furnishing the oxygen and hydrogen necessary to convert the alcohol into acetic acid, probably favours the production of the acid. Moreover, wine diluted with water more readily produces intoxication than the pure wine would do; perhaps, as Dr. Paris has suggested, by applying the stimulus to a larger surface of the stomach ('On Diet,' p. 191).

The classification of wines has engaged the attention of almost all writers who have treated of them; but no satisfactory one can be presented. Jullien, in his very valuable 'Topographie de tous les Vignobles connus,' has given a geographical one, followed by an arrangement of the wines of each country into five or fewer classes, distinguishing the wines, simply so called, from the vins de liqueurs, and subdividing each into the red and white. This for all commercial purposes is sufficient; but for dietetical, or as a guide to individuals desirous of procuring wine for their own consumption, is futile. The greater number of the different kinds mentioned are never heard of beyond the district where they are produced, either from being entirely consumed by the inhabitants, or from the difficulty or expense of transport, or from deficiency in those qualities which ensure their preservation or recommend them to distant lands. This is especially the case with what are termed the fourth or fifth growths, which are seldom, even in good years, worth the expense of transport, if sold under their real names and at their just value. The first, second, and even third growths in good years, bring a price on the spot which puts it out of the power of persons not possessed of large capitals to obtain even a small stock of them. The principal English shipping-houses at Bordeaux and the first-rate houses in this country make their purchases only in the good vintages; and it is their competition which then raises the price, and the absence of their demand which makes it sink again in the unfavourable seasons. First-rate wine must always be high priced, if it be borne in mind that the market-value of a renowned vineyard is very great; that the territorial extent of such is in general very limited; that the expense of cultivation is very high; that these expenses are as great in the bad years, when they bring no return, as in the good years; that the recurrence of favourable vintages are rare and distant; and that constant superintendence and expense are necessary till the wine reaches perfection—not to mention the loss from evaporation, ullage, breakage, and other accidents, and to say nothing of the accumulating interest of the original purchase-money for twenty or thirty years. Besides all these, the duty, though paid in the first instance by the merchant, is recovered by a charge on the consumer.

Attention is now being paid to the culture of the grape and the making of wine in the United States, South Africa, and Australia; with a view of determining whether temperate climates, and English or Anglo-American industry, can introduce this as a profitable culture, The taste of English wine-drinkers has been unquestionably vitiated by the long use of highly-brandied Spanish and Portuguese wines; the taste for light German and French wines, even if the price were low, is by no means extensive in England; and as the new vintages above-named would bear more resemblance to those of France and Germany than to those of Spain and Portugal, they will have some difficulties to contend against. Nevertheless, it is highly desirable that the new attempts should have a fair trial. When Professor Wilson reported on the New York Exhibition of 1853, he stated that vineyards are rapidly extending in that country, principally in Ohio; twelve kinds of grapes are cultivated for the purpose; and the matter is an interesting one to English colonists, seeing that the climate of Ohio is very much like that of many of our colonies.

Of the South African wine which is now coming over to this country, it is to be regretted that the importers give it such names as "South African Port," "South African Sherry," &c. If it be a pure and pleasant wine, it should depend on its own reputation, and not on the attempts to imitate what are really mixtures of wine, brandy, and adulterants.

In 1856, the Society of Arts awarded a silver medal to the grower of four kinds of wine from Australia, three white and one red. Two of the white kinds were satisfactory; one much resembled Cape wine, while the other was a dry and clean wine, with considerable body. The red wine was light, clear-tasted, and exactly like Bordeaux. These wines were made by Mr. Marking, in 1853 and 1854, at Irrawory, in the Hunter district of New South Wales. He found that the grapes suitable in Europe would be no criterion for those best fitted for the climate of New South Wales. The colony contains a large area of good vine land, some of which has been made to yield 1000 gallons per acre. It is believed that the freight would not necessarily be large, for the wine would form good ballast for wool ships to England. All the operations for making Australian wine are fully described in the Society of Arts' Journal for 1856. Professor Owen, as one of the jurors of the Paris Exhibition of 1855, said, "In the department for Australia were evidences of the increasing importations from the vineyards of New South Wales. The specimens of wine exhibited by Messrs. Macarthur, King, and Brown, are deserving of special notice. The wines included white wines akin to those of the Rhine; red light wines like those of Bordeaux; Mousseux varieties with a bouquet, body, and flavour equal to the finest Champagne; Muscats and other sweet wines rivalling the Montignac of the Cape. Some of these wines were of the vintage of 1839, bottled in 1842; others had made the voyage round the world in wood. The verdict of the experts (judges) was much in their favour; for, whereas, on the wines of Europe the numbers indicative of quality ranged from as low as 2 to 18, the lowest number assigned to the Australian specimens was 7, the highest 14, and the average number 10½, being as high as that of the wines of Austria, and much exceeding that of the wines of the Cape, or any other wine-producing colony." It has been since stated, however, that the Australians themselves care little for their own wine; those who can afford to drink wine at all, buy the port and sherry, the claret and champagne, of Europe. There is doubtless much of habit and conventionalism in this; nevertheless the exertions of the planters are worthy of all commendation.

Of wines, real or sophisticated, other than the juice of the grape, we speak in WINES, BRITISH. Of the extent and peculiarities of the trade, details will be found under WINE AND SPIRIT TRADE.

WINE, MEDICAL USES OF. These are distinct from the common or dietetical employment of wine. For very young children, wine may be pronounced to be at once needless and hurtful, as was proved by the experience of Dr. Hunter on his own children. The immense number of the children of the lower orders who fall early victims to gin prove it on a large scale. But in the case of great constitutional debility, or in states of exhaustion from depressing diseases such as diphtheria, scarlatina, or gastric fever, small quantities of good wine cautiously administered, are invaluable tonics. The best mode of administering them is, not to give them undiluted, or even simply with water, hot or cold, but with a very small quantity of hot water having mixed with it so much biscuit or rusk as shall form with the wine a *thick* pulp, requiring to be eaten rather than drunk. This prevents the coats of the stomach being so much irritated, and the wine does not so speedily reach the brain to over-excite it. At a more advanced period of life, if rapid growth should occur, wine in moderation is beneficial. But much caution is requisite, lest habits should be formed, difficult, if not impossible to break. Zealous students are sometimes tempted to prop up exhausted nature by wine; but the benefit is only temporary, while the injury is often permanent. Tea or coffee, or coca, [*Erythroxylon Coca:* See STIMULANTS] are preferable.

As life advances, and the circulation becomes languid, wine in moderation, at fit times, is commendable. It has been designated "the milk of old age," and may tend to prolong life—but in excess cannot fail to shorten it.

The selection of the kind of wine must be left to the individual, or to the judgment of his medical attendant. Every one should aim at obtaining *good* wine, and avoid mixing wines. Where gouty persons use wines, it should be Rhenish, Moselle, or Bordeaux (Claret), and these should be strictly adhered to.

In the treatment of fever, common or typhoid, there generally occurs a stage when stimulants are requisite. Of these, wine is most frequently employed. But as the type of fever so frequently varies, no rules can be laid down. Nothing shows the discriminating power of the physician more than his ability to decide when it is to be used, and how much is to be administered. States of great prostration need much. Port wine, Madeira, and Champagne are mostly preferred. But if erysipelas or affections of the liver occur, Moselle with Seltzer water is best. Tympanites is often dissipated by wine, given either by the mouth, or as an enema. (Abercrombie on the 'Diseases of the Stomach.') The same author gives cases where delicate females, unaccustomed to the daily use of wine, had been saved by the liberal use of wine, in cases of much exhaustion. But these are very extreme cases. Wine, especially port wine, given with very warm water, to persons much exhausted with over walking, or during convalescence from fevers or other weakening diseases, before out-of-door exercise can be taken, often insures sound refreshing sleep if administered about the usual time of going to bed. A rusk or biscuit steeped in it converts it into a digestible supper for such persons.

WINE AND SPIRIT TRADE. It will be convenient to treat this subject under two sub-headings.

Wine Trade. The wine trade of England has been governed for a century and a half almost wholly by a particular treaty with Portugal, called the Methuen Treaty; chiefly by creating an artificial taste for that particular wine which happened to be most easily procured. During many centuries, almost the only foreign wines consumed in England were French. In 1693, a change began, by favouring Portugal wines with a lower import duty; the favour was increased in 1697; and in 1703, Mr. Methuen negotiated a treaty, whereby England engaged to admit port wine at a duty of one-third less than that on French wine; on condition that Portugal received English manufactured goods on favourable terms. The English wine-drinkers, in fact, were sacrificed to the English manufacturers; and the effects have been apparent from that day to this. During the greater part of the last century, England took twenty times as much Portuguese wine as French wine, until the taste for the latter became almost extinguished, except among the wealthy classes. The wine-growers on the Douro and the great merchants at Oporto, finding they had nearly a monopoly, worked it in the usual way to their own profit. An Oporto Wine Company, established in 1754, purposely diminished the extent of the vineyards, with a view of keeping the price wholly under their own command; and this policy was successful until quite recent times. Almost every gallon of port wine was sent to England; other countries either did not like it, or would not pay the price demanded for it. The *natural* flavour and quality of the wines of the Upper Douro are almost unknown in England, and probably would not be relished; they are strongly flavoured for the English market, and require to be kept many years in the wood and in bottle, before they acquire the qualities familiar to English port drinkers.

In 1819 a reduction was made in the duty on French wines; and in 1831 the duty on *all* foreign wines was equalised—after 128 years of favouritism to Portugal. The consumption of port did not, however, yield to this change; because the English had become accustomed to the taste of that wine, and had not yet learned to appreciate the light wines of France. So signally was this the case, that in 1842, eleven years after the equalising of the duty, the English consumption of French wines barely amounted to one gallon for every sixty persons: the total consumption of all wines was about a quarter of a gallon per head, whereas, so far back as the year 1700, it was a gallon a head. It is well known that wholesome wine, of fair quality, can be exported from France at sixpence per bottle; and it still remains to be seen to what degree England will be able to avail herself of this advantage. It was stated before the Committee on the Wine Duties in 1852, by Mr. Forrester, an extensive wine-grower in Portugal, that no port is brought to England with less brandy in it than three gallons to a pipe of 115 gallons; and that the ratio varies from this minimum up to a maximum of 17 gallons. Unfortunately, too, many other substances besides brandy are added in all except the best kinds of port.

From 1697 to 1785, the quantity of foreign wine imported annually never varied far from 2,000,000 to 3,000,000 gallons; from 1786 to 1851 it varied from 4,000,000 to 11,000,000. The Portuguese wine (port) maintained an ascendancy over Spanish (sherry) till about 1830; since which year the balance has been rather the other way. The difference in the above-named quantities was in the *imports;* the *home consumption*, from 1830 to 1860, remained remarkably constant, never deviating far from an average of 7,000,000 gallons. The duty remained steady during that period (about 5*s.* 6*d.* per gallon, or 11*d.* per bottle), and the consumption barely increased as rapidly as the population.

At present, port is gradually giving place to sherry. The entries for home consumption of all kinds of foreign wine, in 1860, were as follow:—

From	Spain	2,975,769	gallons.
,,	Portugal	1,776,138	,,
,,	France	1,125,599	,,
,,	South Africa	426,556	,,
,,	Dutch possessions . . .	222,725	,,
,,	Italy and Naples	205,084	,,
,,	All other countries . . .	626,321	,,
		7,358,192	,,

Of this total quantity, 3,001,413 gallons belonged to the class of *red* wines, and 4,356,779 to that of *white*. The most noticeable feature in that year was the advance in the French wine trade. In 1857, 1858, and 1859, the French wine drunk averaged about 600,000 gallons annually: in 1860 it was nearly double. This resulted from only a few months' operation of the new tariff, which opened the way for the introduction of French wines at a moderate duty. By the Customs Duties Act, passed August 28th, 1860, foreign wines, during the remainder of that year, were to pay 3*s.* per gallon, and colonial wines 2*s.* 9*d.*, plus 5 per cent. From and after January 1st, 1861, all wines pay 1*s.* per gallon, if containing less than 18 per cent. proof spirit; the duty rises to 2*s.* 11*d.*, according to the alcoholic strength. There seems something reasonable in this, making the stronger wines pay the higher duty—provided the mode of testing the quality be not too complex and troublesome. [ALCOHOLOMETRY.]

We may here remark that Sykes's Hydrometer [HYDROMETER] is declared by the legislature to be the official means of deciding the alcoholic strength of wines and spirits; but as wine is now to be estimated by the quantity of spirit it contains, attention will naturally be paid to the easiest mode of making the estimate. Mr. Phillips, chemist to the Revenue Department, has reported favourably of Crockford's Patent Spirit Indicator for wines. This apparatus is based on the principle that the boiling point of any spirituous liquor depends on the quantity of contained alcohol. It consists of a spirit-lamp and stand, a boiler and condenser, and a thermometer with a moveable scale graduated to show the degrees per cent. of pure spirit, and fitting with an air-tight plug into the boiler. There is a tin vessel to hold water, which flows thence through a flexible tube to the inlet of the condenser; a similar tube is attached to the outlet whence the water runs to waste. The boiler is provided with a condenser, which returns to it whatever portion of the alcohol is exhaled, so as to include it in the estimate of the sample.

The Refreshment Houses and Wine Licences Act of 1860 is likely to have some influence on the consumption of wine in England. Any shopkeeper may take out a licence, varying from 10*s.* 6*d.* to 3*l.* 3*s.* per annum, according to the rated value of his house, for the sale by retail of foreign wine. The word "retail" is considered to refer to quantities less than two gallons, or one dozen bottles. The wine may be drunk on the premises, under certain specified conditions, and on payment of a higher licence-duty. All liquor sold as wine must contain less than 40 per cent. of proof spirit, or it will be regarded as spirit. Excise officers are to possess large powers in respect of the examination at all times of premises licensed as wine-shops. Standard measures are to be used. Numerous precautions are taken to insure the honest interpretation of the Act—rendered necessary by the fact that spirits now pay *ten times* as much duty per gallon as wine.

Spirit Trade.—The duty on spirits has been heavy for more than half a century past, varying from 200 to 600 per cent. on the value of the article taxed. The quantity of home-made spirits which paid duty rose from 9,000,000 gallons in 1802 to 23,000,000 gallons in 1849, and 26,000,000 gallons in 1854; while in the last-named year foreign spirits (rum, brandy, hollands, &c.) were taxed to the extent of about 5,000,000 gallons. Spirit drinking is *not* increasing among us. In 1858, 1859, and 1860, the home-made spirits charged with duty did not in any one year reach 24,000,000 gallons, being less than in 1854. The foreign spirits in 1860 (slightly greater than in the two preceding years) presented the following quantities:—Rum, 3,700,000 gallons; Brandy, 1,460,000; Geneva, or Hollands, 260,000. British and foreign together, there are about 30,000,000 gallons of spirits for 30,000,000 people, or a gallon per head per annum each.

An interesting matter concerning spirit duties is that of *methylated spirit*. Spirits of wine, or alcohol in a strong form, is used for many purposes in the arts. It is a solvent of resinous substances, which, when thus dissolved, are used in stiffening hats, and in making varnishes. It is used as a solvent in the manufacture of many chemical substances, including the alkaloids and other organic products, largely used in medicine. It is used in the production of ether, chloroform, sweet spirits of nitre, and fulminating nitre; as a solvent or menstruum for administering the animal and vegetable substances used in medicine in the form of tinctures; as a fuel for burning in spirit lamps; as an addition to oil of turpentine or other hydro-carbons in lamps; and as a solvent for essential oils and other odoriferous substances used in perfumery. For all such purposes alcohol is very valuable; but the high price is a bar to extensive use. There is, however, a liquid now well known to chemists, called *methylated spirit*, which will answer for these purposes nearly as well; and as this is not fit for drinking, manufacturers have for some years urged the Excise to remove the duty from it, simply in the interests of productive industry. In 1856, Messrs. Greatorex, Hofmann, and Redwood presented a report to the government on this subject. They tried to produce a substitute for spirit of wine that would not be drinkable, such as sulphide of ethyl, caoutchicine, &c. At last they found that wood naphtha, pyroxylic or methylic spirit, might be so prepared as to be useful to manufacturers, and yet not likely to be used by spirit drinkers as a substitute for gin. Messrs. Turnbull of Glasgow announced that they could make it at 8*s.* 6*d.* per gallon; and others have stated it might possibly be produced for 5*s.* Two gallons and a half of methylated spirit can be obtained from one ton of dry wood. Mr. Smith, the distiller, of Whitechapel, expressed a belief that publicans would not venture, if the methylated spirit were rendered ever so cheap by the removal of the duty, to mix more than $\frac{1}{15}$ part with their gin, for fear of exciting the suspicion of their customers. The chemists reported to the Excise that, in their opinion, methylated spirit might be set free from duty without affecting the ordinary revenue from ardent spirits. "It appears to us that it would be proper to mix the spirit in the distillery, and to declare illegal the possession of the methylated spirit by a rectifier or publican. The retail sale of the methylated spirit would then fall into the hands of druggists and oilmen, who could be supplied direct from the distillers." This advice has been acted on. A small per centage of pure methylated spirit, mixed with alcohol, is allowed duty free; it is suitable for all manufacturing purposes, but is not drinkable, nor can the alcohol be separated from it by any available process. All the government pyrotechnic or artillery compositions are now made with methylated spirit instead of spirit of wine; and the liquid is coming very largely into use.

The duty on spirits underwent changes in 1853, 1854, 1855, 1858, and 1860. In 1860 an act was passed, which repealed wholly or partially no less than twenty-six former acts, embodying all the regulations for the guidance of manufacturers of, and dealers in, spirits. In the same year, another act fixed the duty on British spirits at 8*s.* 1*d.* per gallon till July 17th, 1860, and 10*s.* after that date. By the Customs Act of the same year, foreign spirits pay an import duty about equal to the Excise duty on British spirits, namely, 10*s.* 2*d.* to 10*s.* 5*d.* per gallon.

WINES, BRITISH. British wines, or Sweets, as they are called by the Excise, are sweet beverages made as substitutes for real wine. The making of them forms a part of domestic chemistry or household skill, as well as a branch of trade. Generally speaking they are prepared from the juice of fruits; but a large number of other chemical substances are similarly employed. The common English fruit wines comprise gooseberry, currant, cherry, raspberry, mulberry, strawberry, apple, elder, whortleberry, blackberry, damson, bullace, apricot, orange, juniper, lemon, grape, peach, quince, and mixtures of these. The dry-fruit wines are chiefly raisin, fig, and date. The root wines are such as rhubarb, celery, parsnip, turnip, and beet-root. The flower and sap wines comprise cowslip, elder-flower, rose, clove, gilliflower, violet, carnation, lavender, primrose, balsam, pine-apple, birch, &c.

In the preparation of ordinary fruit wines, the fruit is selected mature and ripe, but not so sweet as over-ripe fruit. The stalks and the damaged portions are picked off. The rest is bruised in a tub, put into a vat, and steeped thirty or forty hours in water, with frequent stirring. The liquor is drawn off. The pulp is pressed in hair bags; sugar, tartar, &c., are added, and stirred for some time. Vinous fermentation then commences; during its continuance the liquor is frequently skimmed, and after three or four days is run off into casks. In about a week, flavouring ingredients are added; and several days afterwards brandy or some other spirit. Fining and racking complete the process. Some fruits are better for boiling before these operations; others would be spoiled thereby.

The Excise authorities first gave the name of *sweets* to raisin wine; but the name became afterwards applied to all the fermented beverages known as British wines. The making of raisin wine as a branch of trade arose in a curious way. In VINEGAR MANUFACTURE it is explained that a substance called *rape*, consisting of the stalks and skins of raisins, forms the best known filtering and clarifying substance for vinegar. When Mark Beaufoy established his vinegar works at Lambeth more than a century ago, he could devise no better way of obtaining rape then by purchasing raisins, steeping them, throwing away all the juicy portion, and retaining the rest. Dr. Fothergill, an eminent physician, suggested to him the making of raisin wine out of the juice, instead of wasting it. He did so; and thus commenced a trade which has been continued by his descendants ever since. The manufacture of raisin wine requires larger appliances than those which relate to familiar English fruits. The kinds of raisins chiefly used are Smyrnas, Malagas, Lexias, Faros, and Cape de Verds; these produce various qualities of wine known by such terms as *dry, sweet, strong-bodied, rich, full,* &c. The wholesale purchases of raisins are made chiefly towards the close of the year; and the wine is made from thence to spring. The hard masses of fruit are beaten open, and steeped in water till the raisins swell and float. All the vinous and saccharine juices are then pressed out by hydraulic-presses, screw-presses, or heavy weights, according to the scale on which the operations are conducted. Fermentation is then induced in the juice by a leaven or yeast. From the fermenting tuns the juice, which is now wine, passes to other vessels, where the racking, fining, and sweetening are carried on.

Home-made wines or sweets paid a small duty until 1834; but the duty was abolished in that year, since which time the extent of the manufacture has not been known.

A maker of sweets may be as honest a dealer as a maker of the best foreign wines; but unfortunately the cheaper wine has come to be used as an adulterant of that which is more costly. There is hardly any possibility now of determining to what extent the rectifier and the British wine maker are, knowingly or unknowingly, concerned in producing imitations of foreign wine. If the name given to the beverage be such as to denote home manufacture, there is no difficulty. There are in the market wines designated British champagne, British port, British sherry, British Moselle, &c. These are made in England mostly from English fruits, by processes in which the rectifier and the British wine maker are concerned. But the great fraud, which recent investigations have brought to light, is the making up of a mixture which shall bear the name and bring the price of foreign wine. It has been estimated that two out of three bottles of all the so-called champagne sold in England are surreptitious: the wine being made chiefly from English gooseberries. Cider is a chief constituent in a very large proportion of the low-priced port. Much of the port imported from Portugal, also, is adulterated. It was proved before a committee of the House of Commons on the Wine Duties, in 1852, that the Portuguese mix elder-juice, apple-juice, sloe-juice, and logwood decoction, in the port wine intended for the English market; and that the Spaniards are not more scrupulous in reference to sherry. They believe that the English taste for wine is so depraved, as to render detection improbable. When the wines reach England, various other ingredients are often added, including oak-bark, turnsole, elder, privet, beet, Brazil-wood, cudbear, red Sanders wood, and catechu—some to hide the fact that a large quantity of water has been introduced, some to imitate the right colour, some the right crust, &c. It has even been found that glass-makers are employed to make bottles of glass having a peculiar chemical constitution, such as to lead to the formation of a sort of skin or scum which shall imitate the "bee's wing" of "fine old crusted port." Many receipts for making so-called port wine are extant, some of which contain *not a drop* of real port. It is known that much of the port sold at public-houses can be made for 1*s.* 6*d.* per bottle, thus leaving a large profit, even when sold at what seems to be a low price.

It may be well to remark that brandy, either real, foreign, or imitative British, is used to mask the use of adulterants in port wine. In imitating most other foreign wines, the produce of the British wine-makers is more especially relied upon.

WINTER, SPRING, SUMMER, AUTUMN. The astronomical meaning of these words is derived from the considerations in SEASONS, and we are told and taught that winter begins at the winter solstice, spring at the vernal equinox, summer at the summer solstice, and autumn at the autumnal equinox. That is, according to the best authorities, it is spring from the middle of March to the middle of June, summer from thence to the middle of September, autumn from thence to the middle of December, and winter from thence to the middle of March again. At the same time the poets and the farmers, who have a much better right than the astronomers to settle the meaning of these terms for common use, agree in placing the rise of vegetation, the pairing of birds, and the first appearance of flowers in the spring; the hay harvest and the ripening of all the earlier fruits in summer; the grain harvest, the later fruits, and the fall of the leaves in autumn; and the heavier frosts, snow, and ice, in winter.

It is impossible to fix a common commencement of the seasons even for the parts of the earth which lie between the Arctic circle and the tropic, which are all that need be considered; for the polar and intertropical regions have each a set of seasons of their own. But this we may safely say, that the agricultural and poetical seasons are earlier than the astronomical ones. All that distinguishes spring from winter begins to take place before the vernal equinox, all that distinguishes summer from spring before the summer solstice, and so on. Most certainly it will be found that the greatest intensity of the several seasons happens, one year with another, at a period not long after the astronomical phenomenon at which the season is said to commence.

When the year is divided only into summer and winter without further subdivision, it is then an exact division to say that the two halves begin and end with the equinoxes. But here the principal phenomena, the solstices, on approach to which heat and cold depend, are in the *middle* of the halves. If we were to divide the year into four seasons, during which the earth should receive from the sun the greatest and least portion of heat in two of them, and intermediate portions in the other two, the four astronomical commencements should be made the middle points of these seasons. The consideration in SEASONS will easily make it appear why, for the same reason as the greatest heat is after the longest day, the middle of the agricultural seasons should fall after the astronomical point of separation.

WINTER'S BARK, the bark of *Drymis Winteri* (Linn.); called also *Wintera aromatica* (Murray and Willd.), the true Winter's Bark, or Magellanic Cinnamon, to distinguish it from the bark of *Canella alba*, or false Winter's Bark. As one of the names imports, this is obtained from a tree growing in South America, from Magalhaen's Straits up to Brazil. It is met with in cylinders, rarely flat pieces (these last are termed *caryocostin*), from one to two feet long, and from six lines to two or three inches in diameter. It is generally freed from the outer rind (which is tasteless and without aroma), and is of a yellowish-red colour, with reddish-brown points, the marks where the leaves and young branches have been. The inner surface is tolerably smooth, more or less clear, of a reddish-brown colour, which serves to distinguish it from the bark of *Canella alba*, which is much paler. The taste is aromatic, sharp, burning, and peppery. The smell, when first broken, is agreeable, resembling a mixture of cloves, cinnamon, pepper, and marjoram.

According to Henry, its chemical composition is resin, volatile oil, colouring matter, tannin, acetate of potass, chloride of potassium, sulphate of potash, oxalate of lime, and oxide of iron. The volatile oil is pale yellow, lighter than water, with a very hot and acrid taste. By standing, it separates into two parts: one, the most abundant, a greenish-yellow liquid; the other (heavier, but lighter than water), white, and of a fatty consistence. The volatile oil of *Canella* is heavier than water: this serves to distinguish them, as well as re-agents, showing in the true Winter's Bark the presence of both tannin and iron, which are wanting in the *Canella*.

Winter's Bark is an aromatic stimulant and tonic, of a very valuable kind, and it is to be regretted that its use has been almost entirely superseded by the false Winter's Bark (*Canella*). Dr. C. F. von Martius says: "This bark deserves the first place among the aromatic tonics of this country—that is, Brazil." When no inflammatory state of the stomach contraindicates its use, in debility of the digestive organs, with loss of appetite, or slow digestion, it is a valuable remedy.

WIRE-DRAWING. Wire is metal elongated into the form of a slender cylindrical rod, often so fine as to be comparable to a thread, by the operation of wire-drawing. This process consists in passing a piece of ductile metal through a series of holes, successively diminishing in diameter, in a hardened steel-plate called a *draw-plate*, so as to reduce its cross-section to the size and figure of the last or smallest hole, increasing its length at the same time in a certain proportion to the diminution of thickness occasioned by the process. Though ordinary wire is cylindrical, the nature of the process of wire-drawing renders it available for the formation of slender rods of any other required figure. An important application of the process to the production of other forms is to the manufacture of *pinion-wire* for time-keepers. This is produced of any required size and number of teeth, and the wire being cut to the required length for both pinions and axis, the teeth are filed away from the portion used for the latter. By this means pinions may be formed at much less expense than by the ordinary process of wheel-cutting. The grooved rims of spectacle-frames are another example of the useful application of the wire-drawing process, they being formed of wire made for the purpose.

In early times, metals were probably beaten out with a hammer into thin plates or leaves, which were then divided into small slips by means of scissors or some other cutting instrument; these slips were subsequently rounded by a hammer and file, so as to form threads or wires. Beckmann expresses his opinion that the rarity with which works made with threads of metal are alluded to strengthens the presumption that the ancients were unacquainted with the process of producing wire or metallic threads by drawing. So long as wire was formed by the hammer, the artists of Nürnberg, by whom it was fabricated, were styled *wire-smiths*, but subsequent to the introduction of the drawing process their designation was changed to *wire-drawers* or *wire-millers*; and as these appellations occur as early as 1351 and 1360, in the histories of Augsburg and Nürnberg respectively, Beckmann conceives that the invention of wire-drawing must be assigned to the 14th century. In all probability the earliest drawn wire was made by hand, but ere long a machine, impelled by water-power, and capable of drawing wire without the intervention of the hand, was introduced. Though the point is not certainly established, this ingenious machine appears to have been first constructed at Nürnberg by a person named Ludolf, who kept it secret for some time, and realised much money by the use of it. Nürnberg also gave birth to many subsequent improvements in the manufacture of various kinds of wire. The precious metals were undoubtedly among the first made into wire; and perhaps brass and iron were not drawn until some time after the invention of the art. Blanch iron-wire, or white wire, is, however, mentioned in a list of manufactured articles the importation of which into England was prohibited by an act of the reign of Edward III., in the year 1463; and in a similar act passed in 1484 both iron and latten wire are mentioned. Anderson records, under the year 1565, the granting of patents to certain Dutchmen or Germans for the prosecution in England of various manufactures, among which is that of wire. He states that prior to that time all English iron wire appears to have been drawn by manual strength, in the Forest of Dean and elsewhere; and that until these foreigners introduced the use of a drawing-mill, the quality of English wire was so bad that most of that used in the country, as well as ready-made wool-cards and similar articles, was imported from abroad. By the year 1630 the manufacture appears to have made such progress, that in a proclamation of Charles I. it is alluded to as a manufacture of long standing, and one which employed many thousand persons; and it is asserted "that English wire is made of the toughest and best Osmond iron, a native commodity of this kingdom, and is much better than what comes from foreign parts, especially for making wool-cards." The proclamation then forbids the importation of foreign iron wire, and of wool-cards, hooks and eyes, and other articles made of it. The first wire-mill in England was set up at Sheen, near Richmond, by a Dutchman, in 1662. The wire-drawing business either following the cloth manufacture or determined by the proximate localities of coal and iron-stone, took deep root in the neighbourhood of Barnsley in Yorkshire. The manufacture of copper and brass wire in this country was commenced about the year 1649, at Esher, by two foreigners; but they used Swedish rose-copper.

For the manufacture of iron wire the very best and toughest iron is selected. Before the process of rolling with grooved rollers had become common, this superior iron was prepared for the drawing-machine by extending it with the hammer into convenient rods, about the thickness of the little finger. These rods were further reduced in thickness and extended in length by a coarse kind of drawing, called *ripping* or *rumpling*, with the kind of machine described by Beckmann as probably the invention of Ludolf. Holland, writing about 1833, states that although this contrivance is now rarely to be seen in the large wire-mills of this country, it remains in use in some old establishments; and also that in France, and among the continental manufacturers generally, iron wire was, until within a late period, altogether drawn by such an apparatus.

In modern practice both iron and steel, but especially the former, are prepared for the final drawing by passing between grooved rollers, made with the greatest accuracy. The rollers used for this purpose are generally at least seven or eight inches in diameter, and are sometimes made to perform 350 revolutions in a minute. A bar of steel thirty inches long and an inch square, heated to redness, is passed between the rollers, through grooves successively diminishing in size, eight times in less than a minute, and is thereby elongated to from twenty to thirty feet. As it would be difficult and inconvenient to pass the rod back between each rolling, in order that it might always enter the grooves in the same direction, three rollers are used, placed one above the other, so that when the wire has passed in one direction between the two upper rollers, it may pass back in the opposite direction between the two lower rollers, and *vice versâ*, thus avoiding any loss of time, heat, or labour in passing it backwards and forwards. For ordinary wire the rods are commonly reduced to a thickness of about one-eighth of an inch by this process. The slender rods thus produced are called, from their appearance, *black wire*, to distinguish them from drawn or *bright wire*; and, on account of its cheapness, such wire is preferred for coarse purposes in which it is either to be painted or concealed from view. It is commonly used by tinmen and braziers for strengthening the rims of pots, kettles, and various kinds of tin-ware and copper-ware. The kind of cast-steel wire of which the best needles and some other articles are made, is not usually submitted to the rolling process, but, after being tilted to about a quarter of an inch square, it is rounded on an anvil previous to elongation by the draw-plate.

In whatever way the metal may have been prepared for the ultimate process of drawing, or whatever may be the motive-power employed in that process, it is essentially the same. The draw-plate is usually formed of a stout piece of shear-steel, about six inches long and an inch and a half in diameter, flattened on one side. It is pierced transversely with several conical holes, the larger orifices of which open upon the flattened surface of the plate, while their smaller orifices are carefully finished to the size to which it is intended to reduce the wire drawn through them. When the holes have become enlarged by use, their smaller orifices are reduced by hammering, and then reopened to the proper size and form by means of a long taper needle called a *pritchell*. The art of making draw-plates has been carried to much greater perfection in France than in this country; and in time of war French draw-plates have been sold for their weight in silver. The French plates consist of a bar of wrought-iron, about two inches broad and one inch thick, covered on one side with a very hard composition called *potin*, which consists of fragments of cast-iron pots, broken with the hammer, and mixed with pieces of white-wood charcoal. One side of the wrought-iron bar is hammered to a furrowed surface, and covered to the depth of about half an inch with pieces of the prepared potin; the whole is then wrapped up in a coarse cloth, which has been previously dipped in clay and water mixed to the consistency of cream, and finally put in the forge. Being more fusible than the wrought-iron, the potin is the first to melt: and as soon as it begins to do so, the plate is withdrawn from the fire and gently hammered; and the heating and hammering are repeated alternately until the union of the two metals is complete. The plate is subsequently reheated, and extended by hammering to double its original length; the harder metal being so perfectly united with the other as to form a malleable alloy with it; and while the bar remains hot the holes are formed by punching. For this operation the bar is four times heated, and after each reheating a finer punch is employed, so as to make the holes taper. The holes are formed from the wrought-iron side of the bar, and are not carried completely through by the plate-maker; the completion of the holes being performed with sharp punches when the plate is cold, by the wire-drawer himself. Another mode of producing draw-plates, practised at one of the principal wire-manufactories in France, that of the Messrs. Mouchel, at l'Aigle, in the department of l'Orne, is by arranging several pieces of wrought-iron in the form of a box without a lid, and filling the cavity with cast-steel. The whole is then covered with a luting of clay, heated until the steel begins to melt, and worked with a hammer in a similar way to that above described. When draw-plates have been hammered up several times, to reduce holes worn too large by use, they become so hard as to require annealing. After every precaution has been observed, draw-plates will vary somewhat in hardness; but those which are too soft for drawing iron wire may be used for brass, while the very hardest are reserved for steel wire.

The modes of determining the thickness of wire, and the improvements in graduation suggested by Holtzapffel and Whitworth for this purpose, are noticed under GAGE.

In drawing wire by hand the draw-plate is laid against two upright pillars fixed on a bench or table, and, the extreme end of the wire to be drawn being so reduced as to enable it readily to pass through the hole, a small portion is drawn through by a lever apparatus. When a sufficient length of wire has thus been brought through the plate, it is secured to a conical or cylindrical drum, which is mounted upon a vertical axis opposite to the hole in the draw-plate. The workman then takes in one hand the coil of thick wire to be reduced, and in the other a lever handle attached to the drum; and while he turns the drum so as to wind the wire upon its circumference, and consequently to draw it through the plate, he imparts a kind of twist to the wire which enters the plate, by a peculiar motion of the hand in which the coil is supported. In drawing coarse wire, which requires considerable power, the workman walks round the bench at each revolution of the drum, carrying the lever round with him; but for finer wire the apparatus is much lighter, and requires very little labour. In factories where inanimate power is used the winding-cylinders are turned by bevil-gearing underneath the bench, and the coil of undrawn wire is placed on a reel. This apparatus is accompanied by an ingenious contrivance which allows the drum to fall out of connection with the gearing, and consequently to cease to revolve, as soon as the piece of wire is drawn completely through the plate. In some cases, as for pinion-wire, which would be injured by winding upon a drum, wire is drawn upon a long draw-bench in a straight line, the power, which is equalised by the use of a fly-wheel, being applied to a winch-handle which, by means of spur-gear, imparts motion to a horizontal rack.

Between the repeated drawings which are requisite to reduce wire, especially of the finer or smaller sizes, to the required degree of tenuity, it is necessary frequently to heat and anneal it, by which processes the fibrous character imparted by the drawing is in some degree removed before a fresh extension takes place. The annealing-oven should be so contrived as to avoid oxidation as much as possible, and to heat all sizes of wire with tolerable uniformity, the thickest being placed in such a situation as to receive most heat; and after leaving it the wire must be scoured or washed to free it from whatever oxide may have formed upon its surface. In order more perfectly to remove the oxide (which, if left on the surface, not only impairs the appearance and the strength of the wire, but also injures the draw-plate) the coil of wire is sometimes immersed in starch-water or stale beer-grounds during the operation of drawing. A curious and important discovery was made some years since at an eminent wire-manufactory, where, in order to heat the acid liquor in which the annealed wire was steeped, some ingots of brass which happened to be at hand were made red-hot and quenched in it. It was subsequently found that, owing to the action of the acid upon the brass, the iron wire had become coated with a thin film of copper, which greatly facilitated its passage through the draw-plate, acting, it would appear, like a lubricating medium. So important was the advantage gained, that the practice has been universally adopted in that factory of using a weak solution of copper in the acid liquor in which iron or steel wire is washed. The film of copper is entirely removed by the last annealing process. The operation of drawing is also facilitated by the free use of grease, or, for the finer descriptions of wire, wax, to lubricate the wire as it passes through the plate. The repeated annealings of steel-wire would deprive it of too much of its carbon, but for the practice, which is not pursued with iron wire, of surrounding it with charcoal-dust while in the furnace. The rapidity of the drawing process must vary with the quality of the metal, the hardest steel wire requiring the slowest motion; but as each successive drawing increases the fibrous or filamentous character of the metal, the rapidity of the extension may be safely increased as the wire becomes more and more attenuated.

Even when made with the greatest possible care, the holes of iron or steel draw-plates will enlarge so much with wear as to render it impossible to draw any very great length of wire perfectly uniform in thickness. To remedy this, Mr. Brockedon obtained a patent in 1819 for making draw-plates, the holes of which consist of diamonds or other hard precious stones. Dr. Ure states that with a plate of this kind mounted with a ruby, pierced with a hole ·0033 of an inch in diameter, a silver wire 170 miles long has been drawn so perfectly uniform, that no difference could be detected either by weighing portions of equal length or by measuring with a micrometer.

Dr. Wollaston communicated to the Royal Society, in the year 1813, a method of drawing wire of extreme tenuity, suitable for use in micrometers. This he accomplished, in the first instance, by boring or drilling a rod of silver, longitudinally, with a hole one-tenth of its own diameter, and then filling it with gold. The compound bar being drawn into wire $\frac{1}{500}$th or $\frac{1}{400}$th of an inch in diameter, the silver was afterwards dissolved in heated nitric acid, leaving a perfect gold wire $\frac{1}{5000}$th or $\frac{1}{4000}$th of an inch in diameter. Finding the operation of drilling the silver rod very troublesome, he subsequently drew platina wire, and cast the silver round it, treating the compound bar as before. Even by ordinary processes, brass wire is made so thin, that gauze may be woven from it which will have 67,000 meshes in a square inch. The extreme ductility of the precious metals is still more strikingly illustrated by the manufacture of what is commonly known as gold wire, but which is really formed of silver gilt, actual gold wire being made only for filagree-work and a few other purposes. In the ordinary mode of making gold wire, a silver rod about an inch thick is covered with leaf-gold, and then extended to the required tenuity by successive drawings and annealings; the proportion of gold allowed to a pound of silver being seldom more than 140 grains, and sometimes as little as 100 grains. Fine gold wire is used for wrapping or twisting round thread to form gold thread; and its beauty is greatly increased, while it is enabled to cover a larger surface, by flattening it between polished steel rollers.

For making needles, cards for the woollen and cotton manufacture, and various other articles into which wire is fabricated, it is necessary to remove the curvature which it receives by being wound upon the cylindrical or conical drum above alluded to. This is done by drawing the wire between pins fixed in a piece of wood, and so arranged as to bend the wire into a wavy line, the flexures of which gradually diminish until they disappear altogether, leaving the wire perfectly straight. The size of wire is commonly measured by means of a gage, which consists of a plate of steel with a series of deep notches or slits at each edge, varying slightly from each other in width, and numbered according to the number given to wire of corresponding size.

Among the many uses to which wire is applied, the manufacture of wire-gauze or cloth is peculiarly interesting. Plainer kinds of weaving are performed by a modification of the common loom, the coarser varieties of woven wire-work produced being used for fences, pheasantries, coarse riddles or sieves, &c.; while the finer sorts are employed for lanterns, sieves, flour-dressing machines, paper-making machinery, window-blinds, &c. Aviaries, flower-trailing, skylights, garden borders, plant-guards, arbours and summer-houses, flower-bed canopies, flower-stands, chairs, garden-seats, window-blinds, bird-cages, fire-guards and fenders, lamps and lanterns, meat-safes, lattice for book-cases and windows, sieves and strainers, all are now made of wire. The property which renders wire-gauze so invaluable in the safety-lamp has been taken advantage of by the Chevalier Aldini for the construction of wire-armour for the use of firemen, which, though very light, is in a great measure flame-proof. Wire-gauze is also formed into dish-covers, baskets, and other useful and ornamental articles, by pressing it between moulds into the proper shape, which it retains permanently. After being pressed into the required form, the articles are strengthened and neatly finished off by the addition of hoops or rings to their edges before they are removed from the mould. Needle-making is one of the most important applications of steel wire. Some of the finest sorts of steel wire are made into watch-springs, in which form they receive an augmentation of value beyond the prime cost of the material probably unparalleled in the whole range of manufacturing industry. Of the delicate hair-like springs alluded to, which weigh only one-tenth of a grain, 70,000 are required to weigh a pound; and it has been repeatedly stated, though perhaps now the statement may be hardly correct, that the value of such springs is half a guinea each; so that while a pound of crude iron cost but one halfpenny, a pound of these delicate manufactured articles produced from it was worth 35,000 guineas. One of the most elegant applications of gold and silver wire is to the production of *filagree* or *filigrane* work. To form this, fine gold and silver wire, often curled or twisted in a serpentine form, and sometimes plaited, are worked through each other, and soldered together so as to form festoons, flowers, and various ornaments; and in many places also they are frequently melted together by the blow-pipe into little balls, by which means the threads are so entwisted as to have a most beautiful and pleasant effect. This kind of work is of great antiquity, and was formerly much employed for caskets, needle-cases, trinket-boxes, baskets, shrines, and various decorations for church furniture; but it has in a great measure fallen into disuse. *Spangles*, or *paillettes*, which are small round leaves of metal, pierced in the middle, and used for ornamenting garments, are also formed of wire. A piece of wire is twisted round a rod like the thread of a screw, and then cut into little spiral rings, each of which, being laid on a smooth anvil, is flattened by a hammer into the form of a spangle.

An important purpose to which iron wire has been recently applied is in the manufacture of ropes, which are very superior in strength to those made of hemp, weight for weight. An account of wire ropes is given under Rope-Making, and of wire bridges under Bridge.

WIRE GAUZE LAMP. [Safety Lamp.]

WIRE-WORM, a name given by farmers to the larvæ of several insects injurious to various crops: they are species of the coleopterous genus *Elater*, popularly known as Skip-jacks, so called on account of their power of throwing themselves up in the air with a spring when laid upon their backs.

The *Elater* (*Agriotes*) *lineatus* produces a larva which is extremely injurious to oats, often appearing in great numbers and destroying whole fields of corn. It attacks the roots, when the leaves turn yellow and die off. The *Elater* (*Agriotes*) *sputator* is another destructive species. Its larva, like that of the last, resembles the common meal-worm in appearance, and may be found at the roots of withering lettuces, by destroying which plant it greatly annoys the gardener. It eats the root as far as the collar, when the plant dies. *Hemerhipous segetis*, another insect the larva of which is called the wire-worm, is less choice in its ravages, destroying plants of all kinds. Fifty wire-worms of this kind have been found preying on the roots of a single plant.

The wire-worm is injurious to all culinary vegetables, also to our various grain crops. The use of rape-cake in powder has been recommended as a manure to the ground drilled for wheat where wire-worms abound; but hand-picking seems to be the only effectual way of getting rid of them. The mole, fowls, and above all, rooks, are their natural enemies; and the last-named bird is a valuable ally of the farmer in following the plough tracks to devour these mischievous larvæ.

WIT, a term which is applied to a faculty of the mind and to the products of that faculty. As a faculty, it denotes not a distinct power, but certain specific modes of using or operating upon the notions or images with which the mind happens to be furnished. It ranges itself under the more comprehensive faculty of imagination, with which by early writers it was generally used as synonymous; they sometimes used it in a sense still more general, as denoting the intellectual faculty as distinguished from the will. The precise boundaries of the term are too unsettled to admit of any strict definition. It may, however, be described generally as consisting in the display of remote resemblances between dissimilar objects, or such at least as have no apparent resemblance. This species of wit is exhibited in great perfection in two poems of a very opposite class, the 'Hudibras' of Butler, and the 'Night Thoughts' of Young: ludicrously by Butler, to display the absurdities of hypocritical pretence; seriously by Young, to add force and point to his reasonings in favour of religious belief and conduct.

Other kinds of remote allusion, often without any actual similitude, but suggestive to the mind, by indirect inference, to make the comparison for itself, are considered as wit, and produce a similar effect of surprise and pleasure.

When, instead of the remote resemblances discoverable in things themselves, the different meanings of the same word are brought into equivocal contact, the operation is called punning, and the product is a pun. [Pun.]

WITCHCRAFT. There is probably no age or country in which there has not existed a belief in the possibility of mortal beings acquiring the use of supernatural powers for the purpose of accomplishing some object of their desire, good or evil. In this, as in other species of superstition, there will be more or less resemblance in the manifestations, wherever or whenever they are exemplified; but that peculiar class of examples which comes under the denomination of witchcraft admits of certain lines of demarcation, which may be serviceable in keeping the subject distinct from others. The proper field of this superstition was among the Christian nations of Europe—those of the north more particularly. It is to be found in full maturity about the middle of the 15th century, and flourished with tolerably equal vigour through Catholicism and Protestantism, till it gradually decayed before the progress of experimental science. In its doctrinal principles it was a mischievous application of the doctrines of Christianity, being held to be a manifestation of the powers of evil operating as antagonists to the authority of the Deity. It was not necessarily used to accomplish evil ends, because many of the accusations of witchcraft relate to acts which as ends are condemned by no known moral code, but which became crimes from the means made use of. The powers of evil thus employed by human beings had their personal embodiment either in the Prince of Darkness individually, or in certain sublunary agents called imps or familiars, the messengers between the contracting parties, who bore in this agency of evil the same position as that occupied by the angels in the holy hierarchy. The return given by the human being for the use of the miraculous powers thus obtained was generally his own eternal soul, which, according to a superstition entertained by the ignorant in all countries where the immortality of the soul is a standard doctrine, it was held to be in the power of the corporeal possessor to convey in remainder, for value given in wealth, luxury, power, or any other object of ordinary human desire. Besides the bargain in which the parties are supposed to covenant openly with each other, each party was usually presumed to have in view the secondary object of cheating the other. German romance, and, since the days of Balzac, French romance, have dealt largely in the horrors attending these mutual efforts of imposition, where the one party is struggling to recover his chances of eternal salvation—the other to abridge the promised rewards, or to shorten the duration of their enjoyment. In its most simple aspect, the struggles of the evil one to cheat his victim are exemplified in the ordinary Scottish superstition that he gives them money which, when they come to use it, is turned into slates or other rubbish; and the same instance is given, by way of example, by Biensfeldius, a German author, who in 1591 published 'Tractatus de Confessionibus Maleficorum.' This author, who is one of the most systematic of the numerous writers on this subject, and is one who, instead of venting the indignation of an excited and terrified mind against the lost agents of infernal power, treats all the horrors of sorcery with the gravity of an analytical philosopher, tells us that there are three elements necessary to the accomplishment of witchcraft: the divine will permitting it; the power of the devil instigating and assisting the operation; and man's corrupt will consenting to be the instrument. It is a further general characteristic of witchcraft, that from the commencement of its history the agents or victims have, in the majority of cases, been females; and that in later times, when the character of the superstition had degenerated both in the magnitude of the objects accomplished and the rank of the actors, witchcraft came to be considered a power exclusively possessed by old women. It is probable that a propensity to attribute the faculty of divination and the art of perpetrating supernatural mischief to females may have legitimately descended from the Pythia of the more early classical times, and the venefica or poisoner of the later periods of Roman history; and that the account of the witch of Endor may have tended to strengthen the opinion. In the superstitions, however, of nations which have had no means of acquiring knowledge from these sources—the African negroes, the North American Indians, and the Scandinavians anterior to their adoption of Christianity—females seem to have always been the prominent agents in the application of the minor supernatural influences. In the practice of witchcraft within the limits assigned to it in this article, it might be possible to find, in the nature of the connection between the supernatural being and the earthly agent, a tolerably sufficient reason why the influence of a female must generally be greater in the infernal court than that of a male. Whoever has perused the full records of the trials for witchcraft, or the books in which the subject is most minutely investigated, will observe how necessarily it must follow that the power of evil being endowed with the masculine gender, and communicating his sex to those spiritual emanations of his power which sometimes in his stead do his bidding upon earth, the mortal recipients of his malign influence must necessarily be of a different sex. The institutional writers on the subject, however, are not found to allude to such a cause, though they lay it down as a general principle that women are more liable to be the agents of Satan than men, a circumstance which Sprenger, in his 'Malleus Maleficarum,' traces to what he calls their inferiority in mental strength, and the natural wickedness of their hearts.

In going back to an earlier period than that which is here assigned as the time when the superstition of witchcraft was full grown, it will be found that the accusations most nearly resembling the more modern offence of witchcraft are of two distinct kinds—attempts to accomplish mischief through the operation of poison or other natural agents, and lapses from Christianity into heathen practices. The Anglo-Saxon laws against sorcery or witchcraft are simply levelled against the practices connected with the heathen worship from which the people had not been long converted. The corresponding accusations in the south of Europe are levelled against intercourse with demons who represent Diana and her nymphs, or Pan and his satyrs; and down to the ancient period of the belief in witchcraft we find the same personages officiating with changed names, and with natures adjusted to the religious opinions of the age. The secrecy with which the Waldenses and other early seceders from the Church of Rome were compelled to hold their religious assemblages, brought upon them charges of indulging in such unhallowed rites as were traditionally considered the characteristics of ancient heathenism. One remarkable practice of which the Waldenses were accused will be recognised by every schoolboy who has heard a witch legend in the nursery: they were called "scobaces," because they rode to their meetings on a scoba, or broom. The 'Narrative of the Proceedings against Dame Alice Kyteler, prosecuted for Sorcery in 1324,' edited by Mr. Wright for the Camden Society, and which is perhaps still more curious from the light it throws on the early conflicts between the ecclesiastical and the civil power than in its reference to this subject, exhibits both the classes of offence here alluded to. She was charged with having prepared noxious compounds, productive of debilitation which ended in death, and also with abjuring her belief in the Holy Church, with having deserted the mass and the eucharist, with having sacrificed to demons, and with having attempted to usurp the keys of the Church by impiously imitating the ceremony of excommunication.

During its earlier stages, the art of witchcraft was in far higher hands than those to which it afterwards descended, and was used for greater purposes. Witchcraft or sorcery was the means by which Joan of Arc was charged with having obtained her power as a warrior. The Duchess of Gloucester was banished to the Isle of Man for sorcery against Henry VI. Richard III. made repeated accusations of this offence, the most noted of which is the charge against Jane Shore. The earlier witch trials in Scotland generally implicate persons of rank. Sometimes the women who are accused are young, and they do not always use their power for mischievous and malicious purposes. Bessie Dunlop, who was tried in 1576, appears to have used her art for no other purpose than the cure of diseases and the performance of other benevolent acts, accomplishing them through the instrumentality, not of Satan or any of his emanations, as they are spoken of in the later canons of witchcraft, but through the aid of an amiable old gentleman, who had the misfortune to be a prisoner among the fairies in Elfland. Alesoun Pearson, tried in 1588, had a long intercourse with Elfland, which appears to have commenced when she was but twelve years old. She had many personal friends among the fairies there, one of whom was her cousin William Symsoun, a doctor of medicine and "ane great scholar." She was in the practice of appealing to her friends in fairyland for the means of curing earthly diseases, and Archbishop Adamson did not disdain to follow a prescription which she obtained for him, his reliance on it being probably not weakened by his acquaintance with the virtues of the principal ingredient, which was claret. These two trials so far exhibit the darker characteristics of the witchcraft of later times, that Bessie Dunlop's adviser from Elfland wished her to put her soul in his possession; and Alesoun Pearson was told that of the fairy host the tithe is taken every year to hell. The method in which the same occurrences are mentioned by writers of different ages shows the progress towards the accepted doctrines of the authorities of witchcraft; and, as may be afterwards more particularly mentioned, both in England and Scotland the investigations of King James did much to establish a settled creed in relation to this dark subject. Wyntoun, who wrote early in the 15th century, in describing the prophecies made to Macbeth, brings the three weird or fatal sisters to him in a dream, and makes him inquire after the auguries of his fate, as Crœsus is made to consult the Pythia. By the time the history had descended to Shakspere's days, it had acquired from the state of opinion on the subject which it passed through such adjuncts as enabled the poet, by selecting the grander and more terrific features, and adding some elements from the current superstitions of his day, to create those hags "so withered and so wild in their attire, that look not like the inhabitants o'th' earth, and yet are on't." Perhaps the latest conspicuous occasion in which rank and beauty have been allied with charges of the nature of witchcraft, is that of the Countess of Essex and Mrs. Turner, in the murder of Sir Thomas Overbury and the practices against the Earl of Essex; but the direct and palpable crimes exhibited in this horrible history throw the attempts at evil through supernatural influences into the shade. When in later ages it ceased to be encouraged by the great and the learned, witchcraft degenerated, till, in the end of the 17th and the beginning of the 18th centuries, it was entirely confined to such persons as Harsnet, so early as the year 1599, describes in this passage:—"An old weather-beaten crone, having her chin and her knees meeting for age, walking like a bow leaning on a staff, hollow-eyed, untoothed, furrowed in her face, having her lips trembling with the palsy, going mumbling in the streets,—one that hath forgotten her Pater-noster, and yet hath a shrewd tongue to call a drab a drab. If she hath learned of an old wife in a chimney end Pax Max Fax for a spell; or can say Sir John Grantham's curse on the miller's eels—All ye that have stolen the miller's eels, laudate Dominum de cœlis; and all they that have consented thereto, benedicamus Domino: why then beware, look about you, my neighbours. If any of you have a sheep sick of the giddies, or a hog of the mumps, or a horse of the staggers, or a knavish boy of the school, or an idle girl of the wheel, or a young drab of the sullens, and hath not fat enough for her porridge, or butter enough for her bread, and she hath a little help of the epilepsy or cramp, teach her to roll her eyes, wry her mouth, gnash her teeth, startle with her body, hold her arms and hands stiff, &c., and then, if an old Mother Nobs hath by chance called her idle young housewife, or bid the devil scratch her, then no doubt but Mother Nobs is the witch, and the young girl is owl-blasted."

There are two causes which account for the similarity often found to exist in the superstitions of different and distant nations:—1. Physical and mental phenomena common to all mankind and to all parts of the globe, producing like effects when brought into the same combinations; 2. A reference to a common origin anterior to the commencement of the superstition, by which the same opinions adopted by families of mankind separated far apart may be traced by ascent to a common parentage. A great portion of the witchcraft superstition of Europe may be traced to both these causes; but at the same time the identity of the phenomena of this mental disease, as exhibited in different nations, is so remarkable, as well as the rapidity with which the opinions adopted in one part of the world travelled to others, that it is evident some other causes have contributed to produce the effect. The similarity of the incidents narrated, not only in the books which convey the knowledge of these mysteries, but in the reports of criminal trials, and even in the confessions of the wretched victims of the creed, is so remarkable, down to the most minute particulars, as to justify the supposition that a large proportion of the witchcraft superstition was propagated by means of books or through the tuition of men of letters; and that thus, in that age of imperfect science, literature became for a time the means of propagating and concentrating the influence of one of the most baneful superstitions which has ever visited the human mind.

Among the most obvious means which the imagination would suggest for indicating to supernatural powers the exact evil effect which they are solicited to produce on mortal beings, would be the symbolical accomplishment or exhibition of its performance on an effigy of the person intended to be injured. The principles of human action which originally suggested this device are so wide spread as to include the deification of idols and the burning of an obnoxious politician in effigy; but in the practice of witchcraft, the method of symbolically producing death or corporal injury is so far uniform as to predicate a systematic opinion on the subject. An image of the devoted person was made of wax and melted before a fire, stuck through with pins or needles, or perforated with arrows. Sometimes the model was of the heart, or some other vital part; sometimes a picture was used in its stead. Ben Jonson, whose 'Masque of Queens' brings together all the prominent witch superstitions to be found in the classic authors, in the commentators, and in the practice of his own days, says in the third charm:—

> "With pictures full of wax and of wool
> Their livers I stick with needles quick:"

nearly a paraphrase of Ovid's—

> " . . . . simulacraque cerea figit,
> Et miserum tenues in jecur urget acus."
> *Heroides*, vi.

Jonson in his notes refers for this practice to so old an example as the epistle of Hypsipyle to Jason, from which the above is taken; he probably had the passage in his eye. He refers also to what he calls "the well-known story" of King Duffus, one of the imaginary kings of Scotland, the legend of whose sufferings is as old as the days of Wyntoun, by whom it is mentioned, but would be searched for in vain among those still older annalists who had not the means of ornamenting their writings with some of the wisdom of the ancients. Jonson says he remembers some such figures having been dug up in a dunghill in his youth. The story of Bolingbroke and the witch of Eye, in Fabyan's 'Chronicle,' illustrates this practice. In Middleton's 'Witch,' Hecate says, "Is the heart of wax stuck full of magic needles?" King James, in his 'Demonologie,' has a very full examination of the operation of this charm; and after receiving so high a sanction, it of course cuts a conspicuous figure in the subsequent witch trials both of England and Scotland. In the latter country it became united with a belief in the unearthly origin of the numerous small flint arrowheads of ancient workmanship, conspicuous for the regularity and beauty of their shape, which are frequently dug up in the north of Scotland. The witches of Auldearne, whose feats are recorded in Pitcairn's 'Criminal Trials,' described a cavern in the centre of a hill where the arch fiend and his attendant imps conducted a complete manufactory of these missiles; the inferior spirits hewing them out of the rough stone, and their master giving each as it was presented to him in a rough state the proper edge and finish, to adapt it for service.

Those objects which, from their connection with death and decay, are apt to produce loathing and horror in the minds of persons whom habit has not made familiar with them, are favourite instruments in the hands of witches, to whom their use seems to have descended from the necromancers. There are few narratives of witchcraft or sorcery, from Apuleius downwards, which do not present us with some of the spoils of the charnel-house. Animals loathsome to the sight from their structure being associated with notions of deformity, or from the venom with which their otherwise feeble frames are endowed, are naturally made use of by those who among the ignorant aim at the possession of supernatural powers. In this respect the medicine-man of the Indians, called on to try his charms when the traditionary usages of the tribe in the application of simples have failed, uses many of the same tools as the witch of the 16th and 17th centuries. In warm climates the serpent, the scorpion, and the lizard are among the charms resorted to; but in colder latitudes the adept must be contented with the toad, the frog, the mole, and the bat.

Cats are animals which hold out many inducements to the imaginative and superstitious. They bring to a certain extent the habits of a wild beast into the domestic circle. The contrast between their strength and agility, their gentle and fragile appearance, their tenacity of life, their silent and rapid movements, their mysterious gatherings at night and strange cries, invest their presence with a fascinating mystery. The tombs of Egypt and the history of the Knights Templars show that they have received attention in other quarters; but the very peculiar position which they hold in the councils of the powers of darkness, in connection with the ministrations of witches, shows by its uniformity that the opinions regarding them entertained by the authorities on witchcraft lore were widely adopted by the faithful. In several of the Scottish trials and confessions women are found to have assumed the shape of cats, and to have betrayed their pranks by exhibiting when restored to human form the wounds inflicted on them in their bestial capacity. At so late a period as the year 1718 a solemn judicial inquiry was made in the shire of Caithness, by the sheriff or local judge, into the persecutions suffered by William Montgomery, whose life was rendered miserable by the gambols of a legion of cats. The narrative of the circumstance, as given in Mr. Kirkpatrick Sharp's introduction to Law's 'Memorials,' is a lively and somewhat exaggerated picture of those general tumultuous gatherings of domestic cats which sometimes so unaccountably disturb the repose of a neighbourhood. The animals, it was solemnly maintained by the persecuted man's servant, "spoke among themselves;" and at length Montgomery, his patience being entirely exhausted, fell upon the conclave with a broadsword and an axe, and dispersed them with several casualties. The consequence was, that two old women in the neighbourhood died immediately, and a third lost a leg, which having been broken by a stroke of the hatchet, withered and dropped off. In a curious little book published at Leyden in 1656, called 'Magica de Spectris et Apparitionibus Spirituum,' &c., which is a complete repository of diabolical experience, consisting of a series of narratives extracted without comment from historical chronicles and books of magic, an occurrence is said to have taken place at a town in Calabria, so exactly like the above, that whereas Mr. Montgomery was a carpenter by profession, the hero of the foreign adventure was in the act of cutting wood when he was distracted by the presence of a turbulent bevy of cats, whom he dispersed with his implements. In this case the metamorphosis was made known by a charge being brought against the individual of having assaulted and wounded some women of rank in the neighbourhood, when he disclosed the fashion in which they had appeared, and the affair was hushed up. A belief in the metamorphoses of human beings into brutes is a superstition so widely exemplified in classical literature, and in the sculpture and paintings of all societies of men sufficiently civilised to provide such testimonies of their customs and belief, that it cannot be assigned as a special feature of the belief in witchcraft. The minuteness, however, of the analogy exhibited in the above, and discoverable in many like cases, seems to those who do not believe in the actual metamorphosis to leave no other alternative but the belief, that the doctrines promulgated in one part of the world were in all their minute particulars adopted in another. Lycanthropie, or the conversion of men into wolves, was so prevalent a belief in France and Germany as to be the subject of separate treatises and of various judicial inquiries. It naturally did not extend to Britain. This superstition may be perhaps more distinctly traced to the influence of a diseased imagination than most of the others connected with this subject: by the Greek physicians it is understood to have been treated as a disease. Both the English and Scottish trials frequently illustrate the power supposed to be possessed by those in league with Satan of converting their victims into beasts of burden, which they employ to convey them to the scenes of their unhallowed assemblies. This feat was performed on a large scale by the great army of witches charged with assembling at Blocula in Sweden, in 1669, according to the narrative of Glanvil, in his 'Saducismus Triumphatus.'

A power over the elements is one of those gifts with which superstition will be most likely to invest its invisible agents. In its less striking form it has the aspect of a malign interference with the natural fruits of the earth, either by blasting some particular district, or transferring its elements of fruitfulness that they may increase the produce of some other tract in which the sorcerer is interested. This species of incantation is prohibited by the Twelve Tables (Dirksen, 'Uebersicht, &c. der Zwölf-Tafel-Fragmente'), and the illustrations of it in the witch trials are too numerous to be mentioned. A trading or maritime population living on a stormy coast will endow their malignant demons with a more awful authority over the winds and waves. Olaus Magnus treats largely of the storm-raising powers of the Scandinavian witches. It was on his return from these regions with his wife Anne of Denmark, that King James produced so goodly an array of accusations against witches for aiming against his life; and coming from a spot where such a particular department of witch superstition was prevalent, it is natural that the aspect assumed by the accusations should be an attempt to create a storm at sea for the purpose of intercepting his voyage. In the accusations against the witches of Aberdeen in 1596 and 1597, the record of which is printed by the Spalding Club, the exercise of a power over the elements is one of the charges. In the curious narrative as to Margaret Barclay and others, preserved by Sir Walter Scott in his 'Demonology,' we find the same feature. This specific superstition does not seem to have taken root in England, and Shakspere, whose witchery in 'Macbeth' is essentially Scottish in character, has given it a place there:—

> "Though you untie the winds and let them fight
> Against the churches; though the yesty waves
> Confound and swallow navigation up."

It is a remarkable circumstance that nowhere are the identities between the opinions promulgated in doctrinal works and the practice of witchcraft more fully developed than in the confessions of the witches as produced in official documents. The horrible tortures, which the alarm produced by the supposed existence of a coalition with Satan seems to have prompted men of ordinary humanity to sanction, appear to have generally called from the exhausted victims an assent to whatever narrative was dictated to them, and the inquisitors being learned men, acquainted with the best authorities on the subject, would know how to connect the received doctrines of sorcery with whatever train of real circumstances may have been brought home to the victim. Knowing, in fact, the outline of natural events, they would be able to fill up the supernatural details. Margaret Barclay, tried in 1618, was, according to the record preserved by Sir Walter Scott, subjected to "gentle torture." Sir Walter calls this "a strange conjunction of words;' but it is not without precedent, and we can imagine it taken from Biensfeldius, who tells us of a lady who, in 1590, at Cologne was subjected to "modurata tortura." The Incubus and the Succubus—the former the visitant of females, the latter of males—are prominent in the confessions, and open up a world of psycho-physiological inquiry. These notabilia are enlarged upon in several of the Scottish trials. Reference may be made to the appendix to Pitcairn's 'Criminal Trials,' p. 610, and to a pamphlet called 'History of the Witches of Renfrewshire.' Reginald Scot goes over the same subject, and further curious matter will be found in Glanvil, 'Saducismus Triumphatus;' Sprenger, 'Malleus Maleficarum;' and Delrio, 'Disquisitiones Magicæ.' There is no doubt that some of the confessions were voluntarily made; and that, whether dictated by their own imagination or by their reading, the self-accusers did not speak on the suggestion of others. There are thus two mingled elements in these documents, the separation of which would be necessary to and would materially aid a philosophical examination of the causes which have produced such singular effects: the one would bring before us the physical and psychological causes from which the mind voluntarily imagines itself an actor in such supernatural occurrences; the other would explain the utterance of confessions of such acts by persons who, until they were subjected to torture, never imagined their existence. The confessions made under torture were, however, frequently revoked during moments of mental and physical resuscitation.

The influence on society of a belief in witchcraft was of the most pernicious kind. It gave an unchecked flow to all the malignant passions; some venting them in accusations, others in attempts to practise the nefarious art. In the year 1515 five hundred people are said to have been executed at Geneva on charges of witchcraft; and Remigius, the inquisitor, boasts that he put nine hundred to death in Lorraine. The first person who lifted his voice against these cruelties was Wierus, who wrote in 1568. He and his followers carried on a controversy with Delrio, Bodinus, Scribonius, and others, in which it is generally admitted that the defenders of witchcraft were the more successful logicians. The supporters of old and received fallacies have their compact and complete system of sophistry, and he who would break through it must, like a Bacon or a Locke, possess strength enough to destroy the whole fabric. Wierus and his followers ventured to raise their voice against the method only of the manifestation of Satan's power of diabolical possession, not its existence. Against the brutal practice of swimming a witch to see if she will sink or float, which may be traced as an ordeal succeeding that of the red-hot ploughshares, and which inferred that a body in which an evil spirit dwells is lighter than water, they could do no more than adduce the experimental fact, that the herd of swine into which Jesus cast the evil spirits, running into a lake, were drowned. Of all the early opponents of this superstition the English Reginald Scot, who wrote in 1584, was perhaps the most successful in the employment of an acquaintance with natural operations, a bold scorn of fallacies highly supported, and a ready sarcasm. He was followed by Harsnet in 1599, and in 1720 by Francis Hutchinson, who, however, appealed chiefly to the unlearned, among whom alone the belief lingered at the time when he wrote.

The learned men of Europe generally were believers in witchcraft down to the end of the 17th century. Selden has an apology for the law against witches, which shows a lurking belief. He says that if one believes that, by turning his hat thrice and crying 'buz,' he could take away a man's life; "this were a just law made by the state, that whoever should turn his hat and cry 'buz,' with an intention to take away a man's life, shall be put to death." The logic of Selden's mind, if untainted by superstition, would surely have shown him that a law waging war with intentions incapable of being fulfilled must be both useless and mischievous. Sir Thomas Browne and Sir Matthew Hale were believers in witchcraft, and attested their belief by being instrumental in convictions for the crime. It is supposed that there were no executions for witchcraft in England subsequent to the year 1682; but the statute of 1 James I., c. 12, so minute in its enactments against witches, was not repealed till the 9 Geo. II., c. 5. In Scotland, so late as the year 1722, when the local jurisdictions were still hereditary, and had not been put into the hands of professional lawyers, the sheriff of Sutherlandshire condemned a witch to death. It is worthy of remark, as one of the last vestiges of this superstition in educated and professional minds, that in a work called 'The Institutes of the Law of Scotland,' published in Edinburgh in 1730, by William Forbes, an author deservedly neglected by practical lawyers, after a specific definition of the nature of witchcraft, there is the following passage:—"Nothing seems plainer to me than there may be, and have been witches, and that perhaps such are now actually existing; which I intend, God willing, to clear in a larger work concerning the criminal law." This promised work never made its appearance.

WITENAGEMOTE, literally an "assembly of wise men," from the Anglo-Saxon "gemoth," an "assembly," and "witan," "to know," which has the same root, "wit" or "wis," as the words wit, witness, wise, and the legal phrase still in use "to wit."

Although the chief rulers of the Anglo-Saxon states, nearly down to the time of the Conquest, bore the title of king, and in their charters and letters attached to it many sonorous epithets, yet in fact they were little raised in power above the other chiefs of their nation. To election by these chiefs the king owed his office; and if the sceptre descended in his race, it was by means of the formal recognition of the new king by the nobles in an assembly convened for the purpose. Of this assembly the chief ecclesiastics in the kingdom, archbishops, bishops, and abbots, the judges (if such there were), and the largest landholders formed part. Whether the main body of the people had a voice in this great council is doubtful; but judging by the analogy of the shire motes, and of all the political and judicial institutions of our Anglo-Saxon ancestors, it is probable that the freemen who were near the spot had a right to be present. Any important law or regulation was transmitted for approval or consideration to the various folkmotes. While the folkmotes were small, and the occasions for assembling few, little inconvenience was felt, but ultimately it was found expedient for the king to summon an influential person from various parts of the country, perhaps occasionally the leading man of a folkmote, and thus form an assembly of counsellors, or witenagemote. This change was no doubt gradual, and no precise date can be fixed. It is certain that it was in existence in this form under Ethelstan, (A.D. 931) and that all the sheriffs of counties attended it. In 934 there were present at one of these assemblies the king, four Welsh princes, two archbishops, seventeen bishops, four abbots, twelve dukes, and fifty-two thanes. The members were not elected, in any sense but either nominated by the king or summoned by the assembly after having been constituted; and the members seem to have had the right, or assumed the privilege, of introducing a friend or counsellor.

The powers of the witan were extensive. As a consultative body they had a right to consider every public act which could be authorised by the king: they deliberated upon the making of new laws, which were to be added to the folc-right, and which were then promulgated by their own and the king's authority; they had the power of making alliances and treaties of peace, and of settling their terms; in them was vested the right of electing the king, whom also they had the power of deposing if his government was not conducted for the benefit of the people. They, together with the king, had the power to appoint prelates to the vacant sees; they had also the power to regulate ecclesiastical matters, appoint fasts and festivals, and decide upon the levy and expenditure of ecclesiastical revenue; and, with the king, to levy taxes for the public service. The king, with consent of the witan, had power to raise land and sea forces when occasion demanded. The witan possessed the power of recommending, assenting to, and guaranteeing grants of lands, and of permitting the conversion of folcland (common land) into bocland (book-land), and *vice versâ*. They had also power of adjudging the lands of offenders and intestates to be forfeit to the king; and they acted as a supreme court of justice, both in civil and criminal causes. (Kemble, 'The Saxons in England.')

A witenagemote in the reign of Ethelwolf (855) granted to the church a tenth, with the assent of the kings, thanes, barons, and people. The eighth law of Edward the Confessor names the people; and the 35th law recites that it passed by the common advice and assent of all bishops, princes, chiefs (procerum), earls, and of all the wise men and elders, and of the people (populorum) of the whole kingdom. Sergt. Ruffhead, in his preface to the Statutes, conjectures, confessing at the same time his ignorance, that the folcmote resembled our House of Commons, the ealra-witenagemote our House of Lords, and the witenagemote our privy council. Undoubtedly some of the functions which in far more recent times the privy council has performed did devolve upon the witan; for instance, their approval was required for certain acts of the king; and generally their office was less to devise measures than to consider and to sanction those which were submitted to them.

In concurring in royal charters and grants the witenagemote performed the double office of consenting to and of attesting these gifts or privileges; and here their office was analogous to that of the shiremote, which in those rude days distributed justice rather according to the notoriety of the facts than to any systematic rules of investigating the truth, and qualified itself for this office by requiring that the main transactions touching the rights and property of individuals within its district should pass in its presence.

In those cases where the administration of justice was impossible in the county courts, owing either to their want of jurisdiction, or to the power of one of the parties, the authority of the witan was appealed to; and the nation pledged itself to support the executive power of the king by giving to his arrangements the force of a law. Thus the great family of Godwin earl of Kent was outlawed in 1043, and restored in 1052 by the authority of the witan; in another case the title of a great landholder to estates of which the muniments had been destroyed was acknowledged, and a new deed setting out the bounds was granted.

During the Anglo-Saxon times the possessions of the king, and the ordinary payments made to the crown by every landholder, together with the duties paid by townships, were sufficient for the ordinary wants of the government, especially as the triple duty (trinoda necessitas) of repairing roads and bridges (*bryc-bote*), maintaining the walls of the burghs (*burgh-bote*), and resisting invasion (the *fyrd*), was invariable. The king too was entitled to tolls on goods sold in most markets and fairs, and to customs on imported goods; but in those emergencies when a pecuniary contribution was to be made by the nation, the witan were called on to accede to the tax.

It is very remarkable how these powers have been transmitted to our present parliament, though some have been separated and allocated between the House of Peers and the House of Commons. The witenagemote was of course abolished by the Norman invader; but the idea was evidently preserved and ultimately developed even by the Normans themselves. It assumed a distinct form when Simon de Montfort, earl of Leicester, issued writs in the king's name to the sheriffs of all counties, commanding them to return two knights for the county, and two burgesses for certain named boroughs, to sit in parliament to consult on the affairs of the nation.

(Sir F. Palgrave, *Rise and Progress of the English Commonwealth*, 1832; J. M. Kemble, *The Saxons in England*, 1849.)

WITNESS, from the Saxon *witan*, "to know." [EVIDENCE.]

WOAD (*Isatis tinctoria*) is a plant which was once cultivated in Britain to a considerable extent for the blue dye extracted from it. It has been greatly superseded by indigo, which gives a stronger and finer blue; but on some soils it might still be cultivated to advantage.

The woad is a plant of the natural order of the *Cruciferæ*, classed by Linnæus in the *Tetradynamia siliculosa*. It has a strong tap-root, which lasts two years. The height of the plant when in perfection is from three to four feet. It throws out many branches from the upper part of the stem. The leaves are alternate and smooth, the lower on foot-stalks, large and spear-shaped, the upper embracing the stem and arrow-shaped. The flowers are yellow, in panicles at the extremity of the branches. The fruit is a heart-shaped pod, with two valves containing one seed only.

It requires a good substantial soil of considerable depth and fertility; for the larger and more numerous the leaves are, the more profit is derived from the plant. A wet clay soil is not at all suited to its growth, nor a loose sandy one. When it was largely cultivated in England, old pastures ploughed up afforded the best soil for the woad to grow in. These were often taken at a very high rent for two years by men who made it their business to cultivate the woad and prepare the colour, and who found it a profitable speculation. To have good woad the land should be naturally very rich, or much manure should be intimately mixed with it some time before; nothing but completely decomposed dung should be used, or compost made on purpose a long time before.

The land, having been prepared by repeated ploughings and perfectly clean, is laid into narrow beds with deep intervals. On these beds the seed is sown in February or very early in March. It is sometimes sown broadcast, and the plants thinned out, but sowing it in drills, two rows on a four-feet bed, is much the best practice. The drills are one foot from the edge, with two feet clear between them; some make five-feet beds, and there is an interval of thirty inches between the rows, which allows of better cleaning, and gives the plants more room to spread. When the plants are come up in the rows, they must be thinned out by hand, leaving the strongest about two feet apart; the leaves will soon fill up the intervals. They begin to ripen in June. They are fit to gather when they begin to droop and become yellowish. This should be done in very dry weather, and after the dew is off. The leaves of the woad are either twisted off close to the stems or cut down with a sickle. Great care must be taken that no dirt or earth adheres to them. Some recommend taking off the lower leaves first, when they appear ripe by drooping and turning yellow, and letting the upper leaves remain till they show the same appearance; than nothing but ripe leaves will be gathered. This stripping may be repeated two or three times as the leaves grow again. The plants destined for seed are only stripped once or twice, for fear of weakening them. It might probably be advantageous not to strip them at all, but to leave the whole strength for the formation of the seed, which will be larger, and produce finer plants the next year.

The first gathering of the leaves is the best; they should, therefore, be kept separate to obtain the best dye. As soon as the leaves are gathered, the bed should be well and deeply hoed or dug, to give a fresh impulse to the roots.

The leaves are naturally full of sap, and soon begin to decompose if laid in a heap. They should, therefore, be partially dried, and immediately carried to the mill to be manufactured. The seed will vegetate when two years old, but cannot be depended on after that.

Woad is also occasionally sown as food for cattle; and has been brought forward for this purpose under its French name of "Pastel." Its vigorous growth and hardy nature have recommended it; but it will only grow in very rich soils. There are many other plants as vigorous and hardy, which will thrive well in inferior soils, and therefore are to be preferred. But for its dye this plant is well worthy of the attention of those who have good rich and deep soils.

WOMB, DISEASES OF THE. The organ which is devoted to the retention of the fœtus during the early stages of its development [Reproduction in Plants and Animals, in Nat. Hist. Div.] and which is also called the uterus, is subject to all those pathological conditions which are found in other organs composed of similar tissues. The principal tissues to which attention need be directed are the muscular substance of the uterus and its lining mucous membrane. The latter is continous through the os uteri with the same membrane in the vagina, and the affections of the one are often found in the other. Like the mucous membranes in other organs, those parts may be inflamed or congested, or their function may be disturbed. One of the most common and troublesome forms of disease of these membranes is that which is called leucorrhea, and which is attended with an increased secretion from the mucous membranes. This may or may not be attended with pain and other symptoms of congestion. Where the latter is present, the disease requires a different treatment to those cases where no such symptoms are present. Rest, saline purgatives, and an antiphlogistic regimen is beneficial in these cases. On the other hand, where the pain is slight, and the pain more that of nervous irritation, and there are generally symptoms of a debility and want of tone in the system, there tonics, such as quinine and iron, especially the latter, will be found of great benefit. Rest, cold bathing, and a regimen adapted for debilitated states of the system, should be recommended. These cases are often accompanied by nervous symptoms, which more or less approach the condition of hysteria [Hysteria], and which also require special treatment.

In cases where the congestion is more active, the secretion from the mucous membrane becomes puriform, and has a yellow colour. In these cases the more active measures resorted to in inflammatory affections need be had recourse to. Where such an inflamed condition of the mucous membrane is kept up, ulcers frequently occur on the surface of the membrane, more especially in the contracted portion called the os uteri. These ulcers are frequently attended with excessive irritation of the nervous system, producing intense pain of the back, more especially in the region of the coccyx. The general system also frequently suffers in these cases, and great feebleness and exhaustion is the result. Although such ulcers will frequently pass away by judicious general treatment, it is in such cases that local applications have been found of most especial benefit. Injections of tannic acid, alum, sulphate of zinc, and nitrate of silver, are all to be commended. Occasionally, in inveterate cases, it may be necessary to apply lunar caustic, or even caustic potash, to the ulcer itself. This practice, which is very commonly pursued by French practitioners, does not commend itself so strongly in England.

The tissues of the uterus are especially liable to attacks of malignant disease. The nature however of the ulcerations produced by the development of cancerous formation is essentially different from the ulcerations last spoken of. Nor is there any evidence to prove that simple ulceration ever terminates in the malignant form. It is also important, however painful it may be to know, that where malignant ulceration has been once set up, it can never be arrested. This ought to prevent the local application of such powerful remedies as the actual cautery and caustic potash, which can only add to the sufferings of the patient without producing any beneficial result.

The uterus is subject to the occurrence of fibrous, cellular, and other tumours, which, although they produce great inconvenience, are not necessarily fatal. When these occur on the internal surface of this organ, they are frequently more or less pedunculated, and may be removed by ligature or the ecraseur.

The uterus not being attached directly to the solid framework of the body, is liable from the stretching to which its parts are subject during pregnancy to considerable displacements. It may be tilted over backwards, which is called retroversion; or it may be introverted, or it may sink lower than natural into the outlet of the pelvis, constituting what is called prolapsus uteri. For these mechanical defects various appliances have been made with more or less success.

Functional disorders of the uterus are very frequent in both unmarried and married females. The periodical and sanguineous effusion which passes off from the mucous membrane may be increased in quantity, or decreased, or changed. The amount of the catamenia varies in different women, and in the same woman at different periods of life, but occasionally the increase is so great as to produce fainting, and other symptoms of exhaustion. This is called menorrhagia. It sometimes comes on from over-exertion, on the abortion of the embryo, and all that is generally required is rest, and the same treatment as would be adopted in hæmorrhage from other organs. Sometimes the discharge is produced by an inflamed or congested condition of the uterus. There is pain in the back, and a full quick pulse, and other symptoms of inflammatory action. In these cases an antiphlogistic regimen should be pursued, and active purgatives with other lowering medicines may be given. It often happens, however, that the menorrhagia occurs in quite a different state of the system, and here quinine and sulphuric acid, or tannic or gallic acid, should be given.

The opposite state of this function is called amenorrhea. The suppression of the accustomed secretion may arise from various causes, and where any obvious impropriety can be detected of course this must be prevented. Amenorrhea comes on in opposite states of the system, but it is more frequently a symptom of general debility, and comes on as a symptom of most exhausting and debilitating diseases. Should there be amenorrhea without any other pressing symptoms, aloetic purgatives combined with chalybeates and tonics will frequently be found all that is required. The removal of girls from the impure air of towns to the more invigorating atmosphere of the sea-side is a potent remedy in such cases.

Accompanying either of the before-mentioned affections, or without any increase or decrease of the catamenia, there is frequently great pain. This is called Dysmenorrhea. In these cases the general health should be attended to between the periods of attack, and opium judiciously administered will be found the most valuable remedy in relieving the pain. This secretion is frequently lighter in colour, or presents other changed physical appearances, all of which indicate some general derangement, and such cases should be treated accordingly. The affections of the nervous system which may arise from disordered affections of the uterus are very numerous. Pain may be reflected from the uterus as the centre both upwards and downwards, and the parietes of the abdomen, the loins, and the thighs and legs, may be the seat of acute neuralgic pains. The nerves of motion may in like manner be affected, and convulsive movements or entire paralysis may be the result. Such affections retire when the local affection is removed, and all attempts at curing the secondary diseases will fail until the primary one is removed. [Nervous System, in Nat. Hist. Div.; Hysteria.]

WOOD. [Timber.]

WOOD, DECOMPOSITION OF. [Timber, Preservation of.]

WOOD-ENGRAVING is the art of producing raised surfaces, by excision, on blocks of wood, from which impressions can be transferred by means of a coloured pigment to paper, or other suitable medium, and generally applied to pictorial representations of objects.

The art of cutting both upon metal and wood for other purposes than those which are now understood as printing, ascends to a very remote antiquity. [ENGRAVING.] The Babylonian bricks [CUNEIFORM CHARACTERS] bear inscriptions that have probably been formed by a tool, not much unlike some that are now used in wood-engraving, but with the difference that these characters are incised. The Egyptians seem to have made a very close approximation to printing. Some of their wooden stamps are yet remaining, and are perfectly capable of giving impressions in the manner of our present wood-cuts, though their use was doubtless for stamping on clay or other ductile material; bricks so impressed being frequently found, of which some are in the British Museum.

The earliest application of wood-engraving to the production of a book originated, there can be but little doubt, in China, and about the middle of the 10th century, although it has been contested, chiefly on account of the silence of Marco Polo, whose work was written in the last two or three years of the 13th century. The omission is certainly remarkable; yet on the other hand the date here given does not ascend to the period of Chinese fable, but to a period which is reached by sober historical works, and the dynasty under which it is thus stated to have been invented (that of Soong) became remarkable for the rapid development of literary genius that took place under it. It is stated that the first essay in printing was made by cutting in stone, and transferring the impression to paper, the characters of their language being thus white and the ground black. This was speedily relinquished for the use of wooden blocks, in which the characters were cut in relief, and the appearance when transferred was that of our present books. No material alteration has since been made, except that of introducing pictorial representations, which occasionally form a whole volume, the subjects being sometimes connected so that though each page is from a separate block, they would join and produce a total length of some hundred feet. Such are the illustrations to the Wan Show, "pieces of music and songs sung in the streets on imperial birth-days," being a series of representations of the public entertainments and exhibitions, horse-racing, foot-racing, &c., of which there is a copy in the library of the Asiatic Society. The work itself is in 6 vols., of a size somewhat larger than our demy 8vo, and the illustrations form a separate volume of several hundred pages.

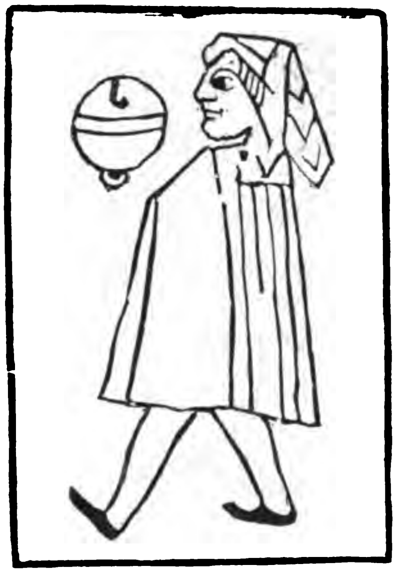
The material used by the Chinese is pear-tree, which is tough, but easy to cut, and of which slabs of considerable size can be procured. The method adopted in engraving and printing is thus described by Sir J. F. Davis, in 'The Chinese, a General Description of the Empire of China and its Inhabitants:'—

"The wooden plate, or block, of a thickness calculated to give it sufficient strength, is finely planed, and squared to the shape and dimensions of the pages; the surface is then rubbed over with a paste or size, occasionally made from boiled rice, which renders it quite smooth, and at the same time softens and otherwise prepares it for the reception of the characters. The future pages, which have been finely transcribed by a professional person on thin transparent paper, are delivered to the blockcutter, who, while the above-mentioned application is still wet, unites them to the block so that they adhere, but in an *inverted* position, the thinness of the paper displaying the writing perfectly through the back. The paper being subsequently rubbed off, a clear impression in ink of the inverted writing remains on the wood. The workman then with his sharp graver cuts away with extraordinary neatness and despatch all that portion of the wooden surface which is not covered by the ink, leaving the characters in pretty high relief. Any slight error may be corrected, as in our woodcuts, by inserting small pieces of wood: but the process is upon the whole so cheap and expeditious, that it is generally easier to re-plane the block, and cut it again, for their mode of taking the impression renders the thickness of the block an immaterial point. Strictly speaking, 'the press of China' would be a misnomer, as no press whatever is used in their printing. The paper, which is almost as thin and bibulous, or absorbent of ink, as what we call silver-paper, receives the impression with a gentle contact, and a harder pressure would break through it. The printer holds in his right hand two brushes, at the opposite extremities of the same handle; with one he inks the faces of the characters, and the paper being then laid on, he runs the dry brush over it so as to make it take the impression. They do this with such expedition that one man can take off a couple of thousand copies in a day."

In Europe, the first application of the art of wood-engraving took place in Germany, though the place is not exactly ascertained, but is supposed to have been near Nürnberg, about the close of the 14th or beginning of the 15th century. It was probably first used for the production of playing-cards, the outlines of which were formed by impressions from wood-cuts, and the colouring filled up by hand; for we dismiss as utterly unfounded the story told by Papillon, in his 'Traité de la Gravure en Bois,' of impressions of a series of wood-cuts seen by him, of a date between 1285 and 1287, executed by Alexander Alberic Cunio and Isabella, his twin sister; although the story is believed by Ottley ('Inquiry into the early History of Engraving'). Zani disproves the story. (See Zani, 'Materiali per servire alla Storia de' Progressi dell' Incisione in Rame e in Legno,' p. 222.)

The origin of playing-cards has been the subject of much contention, and the documents from which conjectures have been drawn as to the date have been singularly subject to perhaps unintentional variations by copyists. Thus the Abbé Rive ('Etrennes aux joueurs de Cartes') quotes a statute of Alfonso XI. of Castile, forbidding the use of cards in 1342; but his authority is only a French translation of a Spanish poem written by Guévare in 1539, and in the Italian translations first published in 1558 no mention is made of cards. John I. of Castile is also said to have issued an edict against the use of them in 1387 (Bullet, 'Recherches Historiques sur les Cartes à jouer'); but here again the authority is a collection of the laws of Spain printed in 1640, while, in an earlier collection, printed in 1541, the same law only forbids the playing at dice and trictrac for money, omitting all mention of cards. The early specimens of cards show that they were of two kinds: one, called *tarots*, was formed entirely of emblematic figures, and was probably used in games similar to those in which now we endeavour to convey instruction in some departments of learning; the other, called numeral cards, was in four suits, bearing different names in various countries, but essentially the same as our present playing-cards. It is almost certain that the first are of Italian origin; they are noticed in 1392, in a life of Philip Maria Visconti, Duke of Milan. In the same year the following entry has been found in the archives preserved in the Chamber of Accounts in Paris:—"Donné à Jacquemin Gringoneur, peintre, pour trois jeux de cartes, à or et à diverses contours, ornés de plusieurs devises, pour porter devers le seigneur Roi, pour son esbattement, cinquante sols Parisis." This, to some extent, confirms the tradition of their being invented for the amusement of Charles VI. of France. If not specially invented, they were brought into early employment for this purpose. These cards were painted, but as they came quickly into general use, the wood-cut was speedily adopted, and, in the Bibliothèque Imperiale of France, ten of the numeral cards are preserved of the date of 1425.

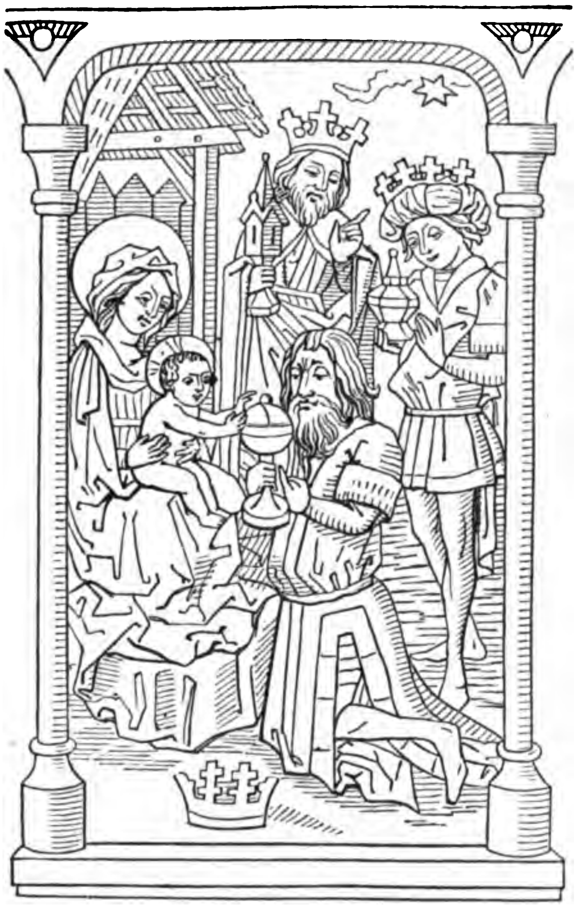
Cards soon became not only an amusement, but an important article of commerce. In the registers of the city of Ulm there is inscribed, in 1402, the name of a burgess who was a painter of cards. In 1418 the burgess-book of Augsburg contains the name of a "Kartenmacher," or card-maker. The trade in cards from Augsburg, Nürnberg, and Ulm became so great that Venice prohibited their importation, and in Sicily they were imported by the cask. It is thence almost certain that it must have been by means of some facility in multiplying copies that they could have been manufactured so cheap as to command so extensive a demand in foreign countries, but none of the specimens now remaining enable us to fix any precise date to their production. We give one specimen, copied from Mr. Singer's work on playing-cards:—



Knave of Bells.

Jäger ('Kunstblatt,' for 1833) found, under the year 1398, the name of one Ulrich, a wood-engraver (Formschneider), but whether he cut blocks for cards, for seals, or for prints, is at least doubtful. (Passavant, 'Le Peintre-graveur,' i. 11.) There also occurs, in the necrology of the convent of the Franciscans, at Noerdlingen, which terminated at the beginning of the 15th century, the name of a lay brother, Luger, who was an excellent engraver in wood. ("Optimus incisor lignorum;" Heller, 'Geschichte,' p. 25.) Luger was probably, as Passavant suggests, an engraver of religious subjects, and several wood-cuts of a very early date are still extant, which, if not executed in a monastery, were executed for one. (See list in Passavant, i., p. 22, &c.) But the first wood-cut with a date known to be in existence is of 1423. It was discovered by Heineken, pasted on the cover of a manuscript in the library of the convent of Buxheim, near Memmingen, in Suabia, and is now in the library of Earl Spencer. It represents St. Christopher carrying our Saviour on his shoulders across a river. The two figures are drawn with much spirit; but the accessories, a man with a loaded ass, a hermit holding up a lantern, and a man ascending a steep path toward a house, show a deplorable want of knowledge of perspective. It is by no means certain, however, that this print is the most ancient specimen we possess, as there are several others which, from their greater rudeness, have been held to have superior claims to antiquity. But this rudeness cannot be accepted as a proof, as there is reason to believe that these scriptural subjects were addressed to the wants of the poorer classes, and were intended to supply the place of the more costly illuminations of the rich, while they admitted of being made to occupy a middle place by being finished off by hand in colours; and, indeed, many of the remaining specimens owe part of their rudeness to the defect of parts intended to be so supplied. Cheapness was therefore an element necessarily required in the production of these prints.

The art, however, made rapid progress. The next great step was the production of block books and the adoption of moveable letters. [PRINTING.] Without entering into the disputed question of the dates of the 'Biblia Pauperum,' the 'Speculum Salvationis,' and others, it will be enough to say that they prove the extension of its use, and many of the early books with moveable types were illustrated with pictorial wood-cuts. Of one of these works we subjoin a fac-simile specimen. A selection of rare and beautiful specimens of block-books, including the 'Biblia Pauperum,' supposed to be the earliest, and the 'Opera nova Contemplativa,' the latest block-book, is exhibited in the British Museum, cases 1 and 2 in the Grenville Library.



Wise Men's Offering.

Maps also were engraved on wood. In an edition of Ptolemy, printed in 1482 at Ulm, there are twenty-seven; and in a later edition, printed at Venice in 1511, the outline, with the mountains and rivers, is in wood, while the names are printed with type, and in two colours, no doubt by separate workings. In England, the original map of London by Aggas, measuring 6 ft. 3 in. by 2 ft. 4 in., to which the date of 1560 was assigned by Vertue, though it was probably some years later, was on wood in several blocks, worked on separate sheets of paper. In 1486 the improvement known as "cross-hatching," by which the bold and free effect of a pen-drawing was endeavoured to be attained, was shown in Breidenberg's 'Travels,' printed at Mentz. This invention has been usually attributed to Michael Wohlgemuth, the master of Albert Dürer. This work, however, preceded by seven years the Nürnberg Chronicle, said to be by Wohlgemuth, but who probably only furnished the designs, and the execution of the cuts is in a very superior style to that of any existing contemporary production: two fac-simile specimens are given in 'A Treatise on Wood-Engraving, Historical and Practical,' executed by J. Jackson, the most complete work that has been produced on the subject in this country, and to which we are much indebted, although we have been compelled to differ from some of the opinions therein.

The art had now attained an excellence which induced artists of celebrity and talent to select it as the means of conveying their designs to the world. Among the most distinguished in this line was Albert Dürer, whose productions as a painter, and an engraver on copper and wood, are so numerous as to excite a doubt whether he was actually an engraver on wood himself, or whether he only put the design on the blocks, leaving them for other hands to execute. The majority of critics regard it as certain that Dürer engraved many of his own designs; the inequality of execution of those marked with his monogram forbids the belief that all were from the same hand. Bartsch, in his 'Peintre-Graveur,' and the writer of the work above mentioned, 'A Treatise on Wood-Engraving,' have agreed that Dürer did not engrave on wood. The last-named says, of all the wood-engravings marked with the initials of Dürer, about two hundred, "the greater part of them, though evidently designed by the hand of a master, are engraved in a manner which certainly denotes no very great excellence, and that none are so superior as to challenge a belief that they must be from his own hand; but he acknowledges that "the cuts of the 'Apocalypse' (published in 1498), five years after the Nürnberg Chronicle, and eight from the expiration of his apprenticeship) generally are much superior to all wood-engravings that had previously appeared, both in design and execution." Yet he asserts that this superiority in execution does not arise from any delicacy or skill in the engraving, "but from the ability of the person by whom they were drawn, and from his knowledge of the capabilities of the art." Another argument is the frequent employment in his cuts of cross-hatching, a work of no artistic difficulty, though one of minute and tedious labour, and which, as an artist, he could have easily avoided. This argument is also applied to others, Cranach, Burgmair, &c., who, it is urged, as draughtsmen on the wood, produced shade thus more easily than by thickening the lines, though in cutting the case is reversed. The last argument is, that, with his other avocations, Dürer could not have found time to execute the great number marked with his name. On this we may remark, that a knowledge of the capabilities of the art was most likely to have been acquired by practice—a fact that is felt even at present by persons who draw on wood; and it is remarkable that in the 'Apocalypse' the use of cross-hatchings is much more sparing than in many of his later works. There can be little doubt that, as he advanced in reputation, he availed himself of assistance not only in wood-engraving, but in painting and engraving on copper. It is known that he had many pupils, and of course it was in this way they were instructed. His wood-cuts are marked precisely as his engravings on copper are marked, and we think there are thus grounds for supposing that the cuts of the 'Apocalypse' are chiefly from his own hand, and that in the others he at least closely superintended their execution and gave the finishing touches. There is much in his designs that patient fidelity could successfully copy, but there is much of artistic feeling and expression that none but an artist of great talent could reach: we refer, as an example, to the Christ taken from the Cross, of which the block still exists, and from which impressions were printed in Ottley's 'Inquiry into the Origin and Early History of Engraving,' and in which the cross-hatching is but sparingly, though effectively, introduced. It is yet a common practice for engravers to employ their pupils in the more tedious and mechanical parts of their business, and this might lead him to adopt the cross-hatching more frequently than in those executed by his own hand, in which, however, he would not altogether omit it, as it was then understood to be an improvement. It would be hard, however, in such cases to withhold the merit of the engraving from the master because he had been assisted perhaps by various persons, according to their capacity, under his immediate supervision. This is also Ottley's opinion. He says, "Dürer or Burgmair might have found employment for a dozen young men;" and that of the Abate Pietro Zani ('Encyclopedia Metodica critico-ragionata delle Belle Arte,' Parma, 1821). On the other hand, Passavant, who has collected the whole of the evidence, and many of the opinions, on each side ('Peintre-Graveur,' vol. i.) inclines to the belief that Dürer's designs were certainly for the most part engraved by professional wood-engravers.

Thus much we have thought it necessary to urge in favour of Dürer's claims to be considered as an engraver on wood, though doubtless his merit as an artist is to be estimated rather from his other works as a painter, an engraver on copper, and as a sculptor, in all of which he excelled. In the history of the art, however, the question has but little real importance. The prints exist, the date of their production is well ascertained, the progress of improvement definitely marked, let the engravers have been who they might.

In the early part of the 16th century several artists of celebrity were either designers on wood or engravers: Louis Cranach, Hans Holbein, Hans Burgmair, Hans Schaufflein, Urse Graffe of Berne, and, in Italy, Ugo da Carpi. Their initials or monograms are on the works; but their claims to the engraving have been denied by Bartsch and by Passavant, as well as by the writer in the 'Treatise on Wood-Engraving.' To Da Carpi has been attributed the invention of imitating drawings in chiaroscuro, effected by using three or more blocks; but it has been shown that this had been done earlier by Dienecker, if not by Cranach, though Da Carpi most certainly improved on it, and some of his designs are said to have been drawn on the blocks by Raffaelle himself, and many of them are from his designs. Books were also at this period most profusely illustrated; but, with the exception of those from the artists already named, and a very few others of some (though inferior) merit, the illustrations are very rude both in design and execution. The art was chiefly practised in Germany, being greatly patronised by the Emperor Maximilian, for whom Burgmair designed the great work called 'The Triumphs of Maximilian.' Carpi was the only distinguished name out of that empire at this period, and the Italian wood-engravings are, on the whole, even inferior to those produced in the Low Countries.' A selection of the early German and Italian prints in chiaroscuro may be seen in the King's Library at the British Museum.

From about 1545 to 1580 wood-engraving continued to be much used for the illustrating of books, but the style of the designs became much lowered; and during this period the execution of engravings improved in Italy, in Holland, and at Lyon, while in Germany the reverse took place, although the productions of Jost Amman may be deemed an exception, as they are designed with considerable spirit, and executed with great care and neatness. His works are very numerous: one of them, his illustrations to Schopper's 'De omnibus Illiberalibus sive Mechanicis Artibus,' contains 115 prints of the principal arts and trades then practised. From the end of the 16th century, while the art continued to decline elsewhere, the cuts in English works showed visible improvement. About this time, also, it became customary to designate the designer as well as the engraver (they had now become separate professions) in the impression; as, for instance, in the designs by Rubens, engraved by Jegher. From this period there is little to be recorded of essential importance, till the appearance of Bewick, though a regular succession of engravers on wood was kept up both in England and on the Continent. The principal names in England were E. Kirkall, who published prints after old Italian masters, in which the outlines were taken from copper-plates and the tints from wood blocks; and John Baptist Jackson, who resided for some time at Venice, and there executed a series of wood-cuts, intended as facsimiles of drawings by Titian and other of the great Italian masters, somewhat in the manner of those of Kirkall.

Bewick, to whom the revival of wood-engraving is chiefly owing, was born in 1753, at Cherryburn, near Newcastle-upon-Tyne. He was apprenticed in 1767 to Mr. Ralph Beilby, of Newcastle, a general engraver, who undertook anything from book-plates to clock-faces, and Bewick's first efforts in wood were made in engraving diagrams for Dr. Charles Hutton's Treatise on Mensuration; but though it is known that he endeavoured to improve himself in this line, it was in private, for his master had little or no employment of the kind for him. He devoted himself, however, to the art after the termination of his apprenticeship, and in 1775 he received a premium from the Society for the Encouragement of Arts and Manufactures, for the cut of the Huntsman and the Old Hound, which appeared subsequently in an edition of Gay's 'Fables,' published at Newcastle, in 1779, by S. Saint. After a short visit to London, he entered into partnership with his old master in 1777, his brother John becoming their apprentice. He continued the practice of his art, furnishing the cuts to the edition of Gay's 'Fables' just mentioned, and to an edition of 'Select Fables' in 1784. In 1785 he commenced engraving the cuts for his 'General History of Quadrupeds,' for which the descriptions were written by Mr. Beilby, and which was published in 1790. The excellence of the work insured its success, and editions rapidly succeeded each other. The merit of the work, however, did not consist merely in the execution of the cuts. Bewick drew all the designs himself; the drawing was in general remarkably correct, and the backgrounds and little vignettes full of the most natural expression, simplicity, feeling, and beauty. The success of the 'History of Quadrupeds' led immediately to the commencement of a 'History of British Birds,' of which the first volume appeared in 1797, and the second in 1804. Bewick had now taken pupils, and in this work was materially assisted by them.

From this epoch the art has continued to flourish. The pupils of Bewick were numerous, and possessed of great talent; the celebrity of their master procured them immediate employment. Illustrated works became fashionable, at first at very high prices, but by degrees at lower rates, and particularly by the example of the 'Penny Magazine,' wherein it was proved that a low price was not inconsistent with a high degree of excellence in the art of wood-engraving; and as it was thus brought within the reach of the very poorest, the public were familiarised with the best specimens, and a large sale was ensured.

For the purpose of illustrating books, wood-engraving is peculiarly adapted. Being worked in the same manner as type, impressions are produced with great rapidity. Any number of cuts may be printed at once on a sheet of paper that will come into the press or machine, and an almost infinite number of impressions may be taken off without material injury to them. This seems the proper purpose of the art. The attempts which have been made to imitate the effects of copper-plates are misapplied, and the endeavours have been failures. The extreme neatness, length and sweep of line, and bold outline of the copper cannot be reached in wood-engravings; while in depth of shadow and effect they equal even mezzotint, with more distinctness of detail.

It is not necessary to detail the history of wood-engraving beyond this period, as many of Bewick's immediate successors are yet living. Within the last few years, also, the wood-engravers of France, and also of Germany, have made such progress in improvement as to become no contemptible rivals of their English brethren. Nor is it any part of our plan to give practical instructions for engraving, which can only be effectively learned by instruction and practice. A description of the process, as practised in his time, is given by Papillon, in his 'Traité historique et pratique de la Gravure en Bois,' 1766; and a far more detailed account, with all the modern improvements, by Mr. Jackson, in the 'Treatise on Wood-Engraving,' already mentioned. We will only observe that one of the greatest practical improvements, that of lowering the surface of the blocks in parts, so as to graduate the shadows into the lights, was, though not invented, yet brought into use by Bewick, nearly all his blocks being so prepared for working; and that box is the wood now universally used for engraving upon.

(Ottley, *Inquiry into the History of Engraving on Copper and Wood;* Singer, *Researches into the History of Playing-Cards;* W. A. Chatto and John Jackson, *Treatise on the History of Wood-Engraving, historical and practical. With upwards of three hundred Illustrations, engraved on Wood;* W. A. Chatto, *Origin of Playing-Cards;* Heineken, *Idée Générale d'une Collection complette d'Estampes;* Eméric, David, *Hist. de la Gravure en taille douce et de la Gravure en Bois;* Jean Duchesne, *Jeux de Cartes tarots et de Cartes numérales du* XIV^{e} *au* XVIII^{e} *siècle* (published by the Société des Bibliophiles Français); Heller, *Geschichte der Holzschneidekunst.*)

WOOD NAPHTHA. [Methyl. *Hydrated Oxide of Methyl.*]

WOOD-SPIRIT. [Methyl. *Hydrated Oxide of Methyl.*]

WOODS. There are in England many old natural woods remaining, besides the royal forests, although the great demand for timber during the last war has greatly thinned them of their finest trees. When woods were abundant and covered a great portion of the land little attention was paid to the increase or preservation of the trees: kings and lords of manors readily granted to their tenants rights of commonage, with the privilege of lopping the branches, always supposing them to be useless dead wood. The consequence of this is still to be seen in all old forests, especially the royal forests, which never were enclosed or protected. Many fine old trees, whose age can scarcely be guessed at, which are very picturesque objects and a fit study for the landscape-painter, have evidently been lopped, at some time or other, for the sake of the wood for fuel, and for want of care have probably never been in such a state as would afford fine timber for ship-building. Windsor Forest, which has only been inclosed since 1813, affords many specimens of noble trunks now hollowed out by time and the admission of water from above, which might probably still be sound and solid, had they been duly protected, and only those branches carefully cut out which were dead and showed decay. The dates of the inclosures of different parts of Windsor Great Park can be readily discovered by observing the form of the oldest trees.

In many extensive woods on private estates the want of care may be readily seen at the first inspection. Oak-woods are chiefly found in stiff clay soils, where the water is apt to accumulate, by which the roots are injured, and the trees decay before they have attained their full growth. The water should be carefully let off by open drains and ditches, which should be regularly examined and cleared out every year before winter. The surface being thus kept dry, the timber, as well as the underwood, will grow much more rapidly, and the increased value of the wood will amply repay the outlay. Cattle should be carefully excluded from all woods; they destroy the young shoots by cropping them, and do much damage to the underwood. At the time when acorns and beech-mast are plentiful, pigs may be turned in without danger; they will turn up the ground in search of their food, and thus bury beech-mast and acorns, which may vegetate, and grow in time into fine trees; for it is well known that an oak raised from an acorn is always hardier and better rooted than one which is raised in a nursery and transplanted in the woods; and the same may be said of beech raised from the seed.

The sweet chesnut is one of the most useful trees in a wood, provided it has room to grow. Its timber, when of a certain age, is as durable as oak, and the shoots which spring up from the old trunks cut down give the most useful and profitable coppice-wood. When it is recollected that a coppice may be cut advantageously every tenth year, if a calculation be made of the value of growing timber after many years, it will be found that the underwood, properly managed, pays fully as well as the timber. It is usual to cut down such trees as begin to show decay at top, when the coppice is cut; but it is better to anticipate this decay, and cut them when they have ceased to increase from year to year as much as the interest of the money they would sell for amounts to. For example: Suppose that an oak standing measures fifty cubic feet, and with top, lop, and bark, may be worth 10*l.* If it does not increase above two cubic feet in a year, it will not be profitable to let it stand: but if, by cutting down others which interfere with the spread of its branches, its growth can be promoted, it may probably increase so much as to pay a good interest on its value; in which case it would be a loss to cut it. There is a period when the increase of the wood in a tree is a maximum, and this depends on soil and situation. The head and branches contribute much to the growth of the trunk; and unless they have room to spread, the increase derived from the action of the leaves must be checked. On this depends the practice of gradually thinning out young woods as the branches spread, the object being to let in as much air as is necessary, without leaving too great a space between the head of one tree and its neighbours. As soon as the branches begin to approach towards those of another tree, room must be made, by cutting out those trees which appear inferior in shape or in health. In the management of young plantations [PLANTING], it is a question whether it is more profitable to cut down trees at the age of thirty or forty years and replace them with young plants, or to let them arrive at their full size, which, for oaks, will take 150 or 200 years. The calculation is made on the annual increase of the wood, which is said to be greatest when the tree is about thirty years old. It has been often supposed that the slower a tree grows the stronger the wood will be; but this appears to be a mistake. Some wood taken from a very rapidly-growing oak, and some from one which, having been headed down as a pollard, had grown slowly, were tried by the action of a very powerful hydraulic press, and the wood of the quicker-growing tree was found to resist the pressure much longer before it was broken or crushed.

Although it is generally on soils unfit for cultivation that plantations of wood are made, yet there are proofs that, on a deep rich soil worth 2*l.* an acre as arable land, a plantation of oaks, well managed for fifty or sixty years, will pay a better rent than if it had been cultivated as a farm. On such land it is usual to plant oaks in the hedge-rows, where the trees, having room both for their branches and their roots, thrive well at the expense of the farmer. Most old farms consist of small inclosures surrounded with trees, chiefly oak, ash, and elm, according to the soil; and the landlord, having the benefit of their growth, only cuts them when fit for sale. The tenant is scarcely aware of the annual loss he suffers from the shade of the trees, as well as the exhaustion of his manure by the roots. If the inclosures are of the extent of twenty acres or more, a few trees here and there in the banks will not do much harm; but it would be far more advantageous to all parties if the woods and plantations were entirely separated from the arable land. A few single trees here and there in old pastures are both ornamental and useful as shelter for the cattle; but they should be extirpated in all arable fields. Clumps and woods may be made pictures in the scenery, whereas a country consisting of small inclosures surrounded with trees only looks like an immense wood when seen from a small eminence.

Trees of full size are sometimes transplanted to form shelter and ornament to parks and pleasure grounds. Sir Joseph Banks made some experiments in his grounds near Brentford, by cutting off the heads of old elm trees and transplanting the trunks by way of keeping up a proportion between the head and the roots, in the expectation of their growing out, but it failed entirely. Sir James Stuart Monteith, in Scotland, succeeded better by retaining the head, and saving, as much as possible, all the fibres of the roots. The removal of large trees is a troublesome and expensive process, but is often desirable for the production of immediate effect, as in laying-out parks and pleasure-grounds, or in landscape gardening generally. The method now usually adopted is briefly described under PLANTING, col. 553.

Wood is too valuable in Britain to be used for fuel, except in very distant and woody districts. Coals have everywhere superseded it; but wherever woods are cut down, and especially where the roots are grubbed up, they give an excellent and economical fuel for the poor, or to use in the lime and brick kilns. Where old hedge-rows are cleared in the progress of agriculture, it is a common practice to give the stumps and roots found in old banks to the poor, for the trouble of grubbing them up and levelling the ground. This work is generally done in winter; and the wood is stacked into cords six feet long, three feet wide, and three feet high.

In France and other countries where they use chiefly wood for fuel, the trees which are preferred are beech-trees, which are allowed to grow very close in the woods, so as to draw each other up and form long thin stems. They are cut down when about thirty or forty years old, and then do not average a foot in diameter; they are sawn in lengths of a yard, and thus sold, the purchaser generally having them sawn into shorter lengths and split for use. In Paris the trade in wood is very extensive, and employs many hands.

WOODS AND FORESTS. A considerable portion of the royal revenue consisted formerly of the rents and profits of the crown lands, which comprised numerous lordships and honours, together with forests and chaces: from the forests the principal source of profit lay in the fines or amerciamenta levied for offences against the Forest Laws. [FORESTS.] The demesne lands which were retained by the king, or which came to the crown by forfeiture or otherwise, and were farmed out to subjects, were originally very extensive; but owing to the generosity or the necessities of different kings, so large a part of them was granted away, that the legislature was frequently compelled to interpose its authority in order to prevent the total alienation of the crown property. William III. had used the power of alienation so profusely, that upon the accession of his successor, it was enacted (1 Anne, st. 1, c. 7) that no grant or lease should be made of any crown lands for a longer term than thirty-one years or three lives, but permitting houses, &c., to be let for fifty years.

By the 26 Geo. III., c. 87, amended by 30 Geo. III., c. 50, commissioners were appointed to inquire into the state and condition of the woods, forests, and land revenues belonging to the crown. By the 46 Geo. III., c. 142 (altered by the 50 Geo. III., c. 65), an office of surveyor-general of his Majesty's works and public buildings was created; but this and some other offices were incorporated with that of "the Commissioners of her Majesty's Woods, Forests, Land Revenues, Works and Buildings" (2 Will. IV. c. 1, s. 1), who were called "the Commissioners of Woods and Forests," which office or board owed its shape to the statute 10 Geo. IV., c. 50 (amended and extended by 2 Will. IV., c. 1; 2 & 3 Will. IV., c. 112; and 3 & 4 Will. IV., c. 69). The commissioners, who were not to exceed three in number, are appointed by letters patent (2 Will. IV., c. 1, s. 1). They are to make a declaration (5 & 6 Will. IV., c. 62, s. 2, in lieu of the oath required formerly, 2 Will. IV., c. 1, s. 6) that they will faithfully and diligently execute the duties of commissioners.

Their powers are very large. The whole of the possessions (except advowsons) and land revenues of the crown in England, Ireland (10 Geo. IV., c. 50, s. 8), and Scotland (2 & 3 Will. IV., c. 112; 3 & 4 Will. IV., c. 69) are under their management; but the *property* therein still remains in the crown. (1 'Q. B. Rep.,' 352.) They are required, however, to observe all the orders and directions of the Lords of the Treasury touching the exercise of their powers (2 Will. IV., c. 1, s. 3).

The commissioners have the power of appointing and removing various officers, such as receivers, surveyors, &c., whose salaries however are fixed by the Treasury (10 Geo. IV., c. 50, s. 12). They may also appoint stewards of the royal hundreds and manors to hold courts, and different manerial and forestal officers to preserve game, fish, &c.; and they may grant licences to hunt, fish, &c. (Id., s. 14).

They are empowered to grant leases of any part of the crown possessions for thirty-one years (10 Geo. IV., c. 50, s. 22); or, in case of houses, buildings, &c., or building-land, for ninety-nine years (Id., s. 23); but this power of leasing does not extend to the royal forests in England (Id., s. 25), except for the purpose of making railroads (Id., s. 97). The leases are required to contain certain specified provisions, and the lessees are not to be made dispunishable for waste, except in leases of mines, and at the option of the commissioners, in leases for ninety-nine years (Id., s. 27). The leases are to be granted at a rack-rent, and no fine is to be reserved (Id., s. 28), except in building leases, in which a nominal rent may be reserved for the first three years (Id.. s. 30), and a fine may be taken not exceeding one-third of the rent (Id., s. 31).

They may also *sell* any part of the crown possessions, except the forests (Id., s. 34), according to a mode pointed out (s. 35); and they may also sell rents, or manerial or forestal rights, to corporations, or trustees of incapacitated persons, who have estates subject thereto (ss. 39, 40).

They may *exchange* or *purchase* lands, &c. (Id., ss. 42, 52, 98).

They are declared to be exempt from all personal responsibility as to any covenants or contracts they may enter into in their official character (Id., s. 17).

All deeds relating to lands, &c., leased, &c., by the authority of the commissioners are required to be enrolled in the office of Land Revenue Records and Inrolments (10 Geo. IV., c. 50, s. 63; 2 Will. IV., c. 1, ss. 16, 18, 21), and to be certified by the commissioners to parliament (10 Geo. IV., c. 50, s. 125); and all conveyances and sales respecting such lands are to be free from stamp and auction duty (10 Geo. IV., c. 50, ss. 67, 68).

The commissioners are also empowered to give certain notices and claims, and to authorise entries on land for breach of covenant, &c. (10 Geo. IV., c. 50, s. 92), and to compound, in certain cases, for rent (Id., s. 93).

Their accounts are to be audited by the commissioners for auditing public accounts, under the 25 Geo. III., c. 52 (10 Geo. IV., c. 50, s. 19).

The receivers appointed by the Commissioners of Woods and Forests must be land-surveyors (Id., s. 80). They are required to account at stated periods to the commissioners (Id., s. 81), and to transmit all sums received monthly (s. 84); and they are empowered to distrain for rent (s. 90).

Notwithstanding the management of the crown lands is thus vested in the commissioners, and the general power of alienation has been taken from the sovereign, a power is reserved to the crown to grant sites for churches, chapels, and burial grounds, not exceeding five acres in extent, or 1000*l.* in value (10 Geo. IV., c. 50, s. 45); and by 1 & 2 Will. IV., c. 59, s. 1, churchwardens and overseers are empowered, with the consent of the Lords of the Treasury, to inclose a portion not exceeding fifty acres of any forest or waste lands belonging to the crown, lying in or near their parish, for the purpose of cultivating the same for the use of the poor.

Besides this general control over the crown lands, certain powers are given to the commissioners which are referable to the execution of the

Forest Laws. The powers and authorities belonging to the offices of wardens, chief-justice, and justices in eyre (which were abolished upon the termination of the then existing interests by 57 Geo. III., c. 61), are vested in the first commissioner (10 Geo. IV., c. 50, s. 95); and the commissioners are also empowered to make compensation to parties for old encroachments made upon the royal forests where they have been in uninterrupted possession for ten years (Id., s. 96).

The *verderers* of the royal forests are also required to make inquiry as to all unlawful inclosures, encroachments, &c., in their courts of attachment, and may impose fines upon the offenders (Id., s. 100), who may however be proceeded against by the ordinary course of law (s. 103). The verderers may appoint regarders, under-foresters and other officers of the forests and courts (s. 101), and may inquire into their conduct, and fine them for neglect of duty (s. 102). Other penalties may be recovered before a justice of the peace (s. 104); and all such fines and penalties are to be applied to the expenses relating to the forests (s. 105).

As to the general revenue arising from the letting, &c., of the crown lands, the commissioners are directed to pay in the moneys received by them, to a proper account with the Bank of England and Ireland respectively (10 Geo. IV., c. 50, ss. 117, 118) and the chartered banks of Scotland (3 & 4 Will. IV., c. 69, s. 17); and the annual income (after certain deductions) is to be carried to the consolidated fund (10 Geo. IV., c. 50, s. 118; 3 & 4 Will. IV., c. 69, s. 16). The transfer of the revenue arising from the crown lands to the consolidated fund is however the subject of a special arrangement between the crown and the subjects, terminating with the life of the sovereign in whose reign it is made.

The 10 Geo. IV., c. 50, contains some provisions peculiar to Ireland. Leases, grants, &c., of any of the small branches of the royal revenue (s. 128), and the powers appertaining to the chancellor and council of the Duchy of Lancaster (s. 130), are exempted from its operation.

The real property of the crown may be thus classified :—

1. Honours, manors, and hundreds, not in lease.
2. Other lands in the occupation of the crown, either for the personal convenience of the sovereign or for the public service.
3. Forests, chaces, and wastes.
4. Lands, tenements, and hereditaments, held of the crown by lease.
5. Fee-farm rents, issuing out of lands, tenements, and hereditaments, held of the crown in fee-simple.

The second class comprises the following royal palaces and houses :—Buckingham Palace; St. James's Palace; Windsor Castle; the palaces of Hampton Court, Kensington, and Whitehall; the King's House at Winchester; the Palace of Greenwich (converted into a hospital for seamen); Somerset House (used as public offices); the New Palace of Westminster, including the houses of parliament, Westminster Hall, and courts of law. The following palaces and buildings have been pulled down and their sites used for other purposes :—Carlton House; the Mews; Newmarket Palace. The following parks are also included in this class :—St. James's, Hyde, Bagshot, Bushey, Greenwich, Hampton Court, Kew Gardens, Richmond, and Windsor. This class is now under the supervision of the Board of Works mentioned below.

In the third class are included not only the royal forests which have preserved their *jura regalia*, but several nominal forests and chaces, warrens, wastes, &c. The following is a list of the real forests :—In Berks, Surrey, and Wilts, Windsor Forest; in Essex, Epping Forest; in Gloucestershire, the Forest of Dean; in Hampshire, Bere Forest, New Forest, and the Forest of Woolmer and Alice Holt.

In 1851 the offices were finally separated, and to the Board of Public Works and Buildings, and to the officers of this board, was consigned the important task of providing for the people public walks and access to the national buildings and collections. The duty of the state in this respect has only been recognised of late years, and perhaps we owe it to our intercourse with the continent, and especially with France, that it has been at all acknowledged. Fifty years ago Hyde Park and Kensington Gardens were the only public places of recreation open to the crowded and hard-worked population of London; since then, beside the improvements in those two places, and the formation of new streets and squares in those parts of the metropolis of which the land either belongs to the crown or has been purchased by parliament for public improvements, there have been opened the large parks and gardens of St. James's Park, the Regent's Park, and Primrose Hill, at the west and north; the Victoria Park at the north-east; and Kennington Park and Battersea Park at the south-west of London. The palace and grounds of Hampton Court have been repaired and adorned, and the collection of pictures has been arranged and enlarged; and Kew Gardens have been enlarged, filled with the rarest and choicest plants and flowers, and improved by the addition of magnificent conservatories and a new museum, and both Hampton Court and Kew Gardens have been thrown open gratuitously to the public. In Kensington Gardens an Italian garden has been laid out with fountains, statuary, and carving; which though not of very remarkable excellence or originality, are at least superior to anything of the kind hitherto given to the public.

WOODY FIBRE. [LIGNIN.]

WOOL. The present article will be devoted to the SHEEP with reference to its wool-producing properties, and as the subject of the art of the grazier. The natural history of sheep is given under OVEÆ, in NAT. HIST. DIV. The treatment of the fleece when removed from the animal is spoken of under WOOL AND THE WOOL TRADE: see also WOOLLEN MANUFACTURE.

The sheep belongs to the class *mammalia*; to the order *ruminantia* with four stomachs, and the organs of digestion disposed for chewing the cud; to the tribe *capridæ*, with horns persistent, and placed on an osseous nucleus; and to the genus *ovis*, with or without horns, but these when present uniformly taking, to a greater or less degree, a lateral and spiral direction. The forehead of the sheep is arched, and protruded before the base of the horns; there are no lachrymal ducts, the nostrils are lengthened and oblique, and terminate without a muzzle; there is no beard properly so called, the ears are small, and the legs slender. The hair is of two kinds, one hard and close, and the other woolly—the wool preponderating in proportion as the animal is domesticated. The sheep is principally distinguished from the goat by his convex forehead, by his spiral horns not projecting posteriorly, and more especially, and that in proportion to the care which is bestowed upon him, by the preponderance of wool over the hair, with which, in despite of every effort, the Cashmere goat is covered.

Different names are given to the sheep, according to its sex and age. The male is called a *ram* or *tup*. After weaning he is said to be a *hog*, a *hogget*, or *hoggerel*, a *lamb-hog*, or *tup-hog*, or *teg*; and if castrated, a *wether hog*. After shearing, and when he is probably a year or a year and a half old, he is called a *shear hog*, or *shearling*, or *dinmont*, or *tup*; and when castrated, a *shearling wether*. After the second shearing, he is a *two shear ram*, or *tup*, or *wether*. At the expiration of another year, he is a *three shear ram*, &c.

The female is a *ewe* or *gimmer lamb* until weaned, and then a *gimmer* or *ewe hog* or *teg*. After being shorn, she is a *shearling ewe* or *gimmer*, or *theave* or double-toothed ewe; and after that, a *two* or *three* or *four shear ewe* or *theave*. The age of the sheep is reckoned, not from the period of their being dropped, but from the first shearing.

The teeth give certain indications as to the age. The sheep has no incisor teeth in the upper jaw; but there is a dense elastic cushion or pad, and the herbage, firmly held between the front teeth in the lower jaw and this cushion, is partly bitten and partly torn asunder. The sheep has the whole of the incisor teeth by the time that he is a month old, and he retains them until the fourteenth or sixteenth month. They then begin to diminish in size, and are displaced. The two central ones are first shed, and the permanent ones supply their place, and attain their full growth when the animal is two years old. Between two and three, the next pair are changed; the third at three years old; and at four, the mouth is complete. After this there is no certain rule, until, two years more having passed, the teeth one by one become loosened and are lost. At six or seven years of age the mouths of the ewes should be occasionally examined, and the loose teeth removed. By good pasture and good nursing in the winter, they may produce lambs until they have reached the ninth or tenth year, when they begin rapidly to decline. Some favourites have lingered on to the fifteenth or sixteenth year; but the usual and the most profitable method is to fatten and dispose of the ewes when they are five or six years old, and to supply their places by some of the best shearling ewes.

The rings at the base of the horns afford very imperfect indications of the age of the sheep. Even when untouched, they are little to be depended upon.

The history of the British sheep will be most naturally divided according to the quantity and quality of the wool of the different breeds, and the quality of the flesh. The covering of the original sheep consisted of a mixture of hair and wool; the wool being short and fine and forming an inner coat, and the hair of greater length, projecting through the wool, and constituting an external covering. When the sheep are neglected or exposed to a considerable degree of cold, this degeneracy is easily traced. On the Devonshire moors, the mountains of Wales, and the highlands of Scotland, the wool is deteriorated by a considerable admixture of hair. Even among the Southdowns, the Leicesters, and the Ryelands, too many *kemps* occasionally lessen the value of the fleece. It is only by diligent cultivation that the quantity of hair has been generally diminished, and that of wool increased in our best breeds.

The filaments of wool taken from a healthy sheep present a beautifully polished and even glittering appearance. That of the neglected or half-starved animal exhibits a paler hue. This is one valuable indication by which the wool-stapler is enabled to form an accurate opinion of the value of the fleece. The mixture of hair in the wool can often be detected by close examination with the naked eye, but most readily by the assistance of a microscope.

Among the qualities which influence the value of the wool, *fineness*, and the uniformity of that fineness in the single fibre and in the collected fleece have hitherto held a first place. This fineness, however, differs materially in different parts of the fleece. It prevails on the neck, the shoulders, the ribs, and the back. It is less on the legs, thighs, and haunch, and still coarser on the neck, the breast, the belly, and the lower part of the legs. The fineness of the wool is considerably influenced by the temperature. Sheep in a hot climate yield a comparatively coarse wool; in a cold climate, they carry a closer but a warmer fleece.

The fineness of the fleece is also much influenced by the kind of food. An abundance of nutriment will increase both the length and the bulk of the wool. This is an important consideration with the sheep-breeder. Let the cold of winter come—let it continue for a considerable period, yet if the sheep be well kept, although the fleece may lose a little weight, this will be more than compensated by its fineness and increase of value. If the sheep, however, be half-starved while he is exposed to unusual cold, the fibre of the wool, although perhaps somewhat finer, will be deficient in weight and strength and usefulness.

What is called *trueness of staple*, or the fibres being of an equal size, is of much importance in the manufacture of wool, for whenever the wool assumes an irregular and shagged or *breachy* appearance, there is a weakness in the fibre and will be an irregularity in the manufacture, especially if the fleece is submitted to the operation of the comb. Connected with this, and a most important quality, is the *elasticity* of the woolly fibre—the disposition to yield, or submit to some elongation of substance, some alteration of form, when it is distended or pressed upon, and the energy by means of which the original form is resumed as soon as the external force is removed.

Referrible to this elasticity or yielding character of the wool is its *pliability* and *softness*, and without which no manufacture of it can be carried to any degree of perfection. The last quality which it is necessary to mention is its *felting* property, that quality by which it may be beaten or pressed together and worked into a soft and pliable substance of almost any size and form. It would seem that the process of felting is of far older date than that of weaving, and it is still continued not only by the nomadic tribes of south-eastern Europe and of Asia, but it is made occasionally to vie with the finest productions of the loom.

Microscopic observations have unravelled the whole mystery of felting, and of the employment of wool in almost every form. The fibre, examined under a powerful microscope, appears like a continuous vegetable growth, from which there are sprouting, and all tending one way, from the root to the other extremity, numerous leaves, or serratures, assuming the appearance of calices or cups, and each terminating in a sharp point. It is easy to conceive how readily one of these fibres will move in a direction from the root to the point, while its retraction must be exceedingly difficult, if not impossible. It was a fibre of Merino wool that was first submitted to microscopic observation, and the number of these serrations or projections counted. There were 2400 in the space of an inch. A fibre of Saxon wool finer than that of the Merino, and of acknowledged superior felting quality, was substituted. There were 2720 serrations. A fibre of Southdown wool, in its felting power well known to be inferior to that of the Saxony and the Merino, was placed in the field of vision. There were only 2080 serrations in the space of an inch, or 640 less than the Saxony exhibited. The Leicester wool is acknowledged to possess a less felting property than the Southdown. There were only 1860 in the space of an inch. Latterly the length of staple and the lustrous character of the wool have become qualities of high order, so that the long-wools of Lincolnshire are now of greater value than the short-wools of Sussex.

We now proceed to take a rapid survey of the different breeds of sheep, commencing with the *Southdowns;* for by them or their congeners the first woollen manufactory at Winchester was supported. As latterly improved by the Ellmans, Lugars, Rigdens, and Webbs, it has exerted an extraordinary influence for good on all short-woolled breeds of sheep in the country. The flock of Jonas Webb in particular has furnished rams to all the best breeders of short-woolled sheep; and the high estimation in which his breed is held was proved at its recent sale, when 960 sheep of all ages sold for nearly 11,000*l.*

The Southdown sheep have succeeded admirably in all the southern districts of the kingdom; but the northern hills have occasionally been too cold for them. Crosses between the Southdown and almost every breed of middle-wool sheep have answered well; while in counties where it could have been least expected, the old breed is in a great measure superseded by the Southdowns.

We pass from Sussex, Hampshire, Berkshire, Wiltshire, where a black-faced short-woolled sheep, much improved by the Southdowns, prevails, into Dorsetshire, and we find a very different and valuable breed of sheep. They are white; the face long and broad, with a tuft of wool on the forehead; the shoulders low but broad; the chest deep; the loins broad; and the bone small; a hardy and useful sheep. Their chief peculiarity is the forwardness of the ewes, which supply the market with lamb when it produces the highest price.

A very profitable variety is found in a cross between the Southdown and the Dorset sheep. The carcase is increased, and the wool is rendered more valuable.

Returning through Somersetshire, we again meet with the Southdowns, either pure or materially improving the native breeds. In Gloucestershire, the short-woolled sheep have given way to the Cotswolds.

In Herefordshire we still meet with a few flocks of that breed of sheep, which was in former times the pride of the agriculturist—the Ryelands. They are small, polled, with white faces, the wool growing close to and almost covering the eyes, the carcase round and compact, the animal quickly fattening, and the superabundant fat accumulating within. They are hardy, and peculiarly free from disease, and particularly distinguished by the fineness of their wool.

Shropshire contains now a valuable characteristic breed of short-woolled, large-framed sheep, which have of late years achieved a high reputation.

The Cheviots extend from Westmoreland far into Scotland. They differ essentially from both the black- and the dun-faced breeds by which they are surrounded. The following is a description of the pure breed, thirty years ago, before they began to be crossed by the Leicesters:—"The head polled, bare and clean, with jaw-bone of a good length; ears not too short, and countenance of not too dark a colour; neck full, round, and not too long, well covered with wool, but without any coarse wool depending beneath; shoulders deep, full, and wide; chest full and open; chine long, but not too much so; straight, broad, and wide across the fillets; horns round and full; the body in general round and full, and not too deep or flat either in the ribs or flanks; the fleece fine, close, short, and thick-set, of a medium length of pile, without hairs at the bottom, and not curled on the shoulders, and with very little coarse wool on the hips, tail, or belly."

There are many flocks of pure Cheviots, but in the majority of the flocks there is a cross of Leicester blood.

The other breed of short-woolled sheep which contend with the Cheviots in number and value, is the *black-faced Scots.* They extend from Lancashire to the very north of Scotland. The males are mostly horned, the horns of a spiral form, but the females are frequently without horns. The faces and legs are always black or mottled: they are covered with wool about the forehead and lower jaw: the fleece is long and somewhat coarse. The carcase is peculiarly compact; so much so, that on account of the shortness, roundness, firmness, and handsomeness of the carcase, it is called the *short* sheep, in opposition to the Cheviots or *long* sheep. Great numbers of these sheep are sent to the London market. The weight of the carcase does not differ materially from that of the Cheviot, and the fleece weighs about three pounds after it is washed. These sheep have been improved by selection, but have derived little advantage from any of the crosses that have been tried.

We now arrive at the *Long-woolled Sheep.* The following description of the *New Leicester* by Mr. Culley will, to a very considerable degree, serve for all the varieties of the long-woolled sheep. The head should be hornless, long, small, tapering towards the muzzle, and projecting horizontally forwards. The eyes prominent, but with a quiet expression. The ears thin, rather long, and directed backwards; the neck full and broad at its base, but gradually tapering towards the head, and particularly fine at the junction of the head and neck. The neck seeming to project straight from the chest, so that there is, with the slightest possible deviation, one continued horizontal line from the rump to the poll. The breast broad and full; the shoulders also broad and round, and no uneven or angular formation where the shoulders join either the neck or the back, particularly no rising of the withers, or hollow behind the situation of those bones. The arm fleshy through its whole extent, and even down to the knee. The bones of the legs small, standing wide apart, no looseness of the skin about them, and comparatively bare of wool. The chest and barrel are at once deep and round in the ribs, forming a considerable arch from the spine, so as in some cases, and especially when the animal is in good condition, to make the apparent width of the chest even greater than the depth. The barrel ribbed well home. No irregularities of line on the back or the belly; but on the sides the carcase very gradually diminishing in width towards the rump. The quarters long and full, and as wide as the fore-legs. The muscles extending down to the back, the thighs also wide and full. The legs of a moderate length; the pelt also moderately thin, but soft and elastic, and covered with a good quantity of white wool, not so long as in some breeds, but considerably finer.

Such is the Leicester sheep as Bakewell made him. He found him as different an animal as it was possible to conceive—flat-sided, large-boned, coarse-woolled, slow to fatten, and his flesh of little value. Were there room for its insertion, a detailed history of the different steps of the changes would be most interesting to the reader. The means were simple, and the effect was almost magical. The principle was, that "like produces like;" and therefore he selected a few sheep with aptitude to fatten, with a disposition to produce an unusual quantity of valuable meat, with little bone and offal, and with quietness of temper; and from these he exclusively bred. He cared not about near or distant affinities, but his object was to increase every good point, and gradually to get rid of every bad one. They were not different sorts of sheep that he selected, but the best of the breed to which he had been accustomed.

His sheep were smaller than those of his neighbours, but they retained every good point, and had got rid only of the bad ones. The alteration was rapid as well as great in his own flock, and the practice which he introduced of *letting* some of his rams quickly extended the benefit of his system far and wide. The first ram which he let was in the year 1760, at 17*s.* 6*d.* for the season. In 1789 he let one ram for 1000 guineas, and he cleared more than 6000 guineas in the same year by the letting of others. After that, so great was the mania, or desire for improvement, that Mr. Lawrence calculates that 100,000*l.* were annually spent by the midland farmers in the hiring of rams.

The chief value of the new Leicester breed consists in the improvement which it has effected in almost every variety of sheep with which it has been crossed, in which its influence has corresponded among long-woolled sheep with that which the Southdowns has exerted on breeds allied to it in the character of their wool.

The largest of the other breeds of long-woolled sheep was the Lincolns, "hornless, with long, thin, and weak carcases, large bones, weighing from 20 to 30 lbs. a quarter; the wool averaging from 8 to 14 lbs. the fleece; the sheep a slow feeder, and the flesh coarse-grained." This is the account of them given by a good, but a prejudiced observer—Mr. Culley. In fact, while Bakewell and his admirers were almost neglecting the fleece, the Lincolnshire farmer was quite as inattentive with regard to the carcase. Both parties were wrong. The old Lincolnshire sheep yielded a wool which in quantity and in quality was unrivalled, while the Leicesters could boast of a disposition to fatten which the other could never equal. At length the attempt was honestly made to amalgamate the valuable qualities of the two breeds. In consequence of the cross, the wether attained its maturity a full year sooner than it was accustomed to do, and the fleece became finer and improved in colour, but it was shorter and more brittle, and not fitted for some of its former purposes. On the whole, a great improvement has been effected both in the carcase and the fleece; and so satisfactory did this prove, that it is now difficult to find any sheep in Lincolnshire that have not been crossed with the Leicesters. This cross is deeper on the wolds than in the marsh lands, which may serve to account for the difference of the fleece in the two. The breed of these sheep generally has been greatly increased since the introduction of the turnip system. The lustrous character of the wools has given them a high value in the manufacture of woollen fabrics, corresponding to those made of Alpaca wool, with which they are mixed.

Among the long-woolled sheep that have been improved by the admixture of the old and new long-woolled breeds and the altered system of husbandry, the inhabitants of Romney Marsh must not be forgotten.

The Cotswold sheep, of Gloucester, were a long-woolled breed, yielding in the 15th century a description of wool much valued on account of the fabrics in the construction of which it was employed. Even they, like the rest, have amalgamated themselves with, and been in a manner lost among, the Leicesters. They were taller than the present sheep, flat-sided, deficient in the fore-quarter, but full in the hind-quarter, not fattening so early, but yielding a long and heavy fleece. Many of these good qualities have been preserved, and to them have been added that which is of so much importance to the farmer—the capability of rearing and fattening so many more sheep on the same quantity of land, and of bringing them so much earlier to the market.

This will be the proper place to speak of the *shearing* of the sheep, or the separation of the fleece from the animal. The animal is first washed in some running stream. Two or three days are then allowed for the drying of the wool previous to its being shorn, the sheep being turned into a clean pasture, and remaining there until the fleece is dried, and that the new yolk, which is rapidly secreted, may penetrate through it, giving it a little additional weight and a peculiar softness. As soon as the sheep is shorn, the mark of the owner is placed upon it, consisting of lamp-black and tallow, with a small portion of tar, melted together. This will not be washed away by any rain, but may be removed by the application of soap and water.

Few rules can be laid down with regard to the rearing and feeding of sheep that will admit of anything like general application. A great deal depends on the kind of sheep, and the nature of the pasture and the food.

Suppose the larger kind of sheep, and on arable ground. The ewes are generally ready to receive the ram at the beginning of October, and the duration of pregnancy is from about twenty-one to twenty-three weeks, bringing the period of parturition to nearly the beginning of March, at which time most of the lambs will be dropped. The ewes should be fed rather better than usual a short time previous to the male being introduced. Rams are fit to propagate their species in the autumn of the second year, and that is also the proper period for the impregnation of the ewes. The ewe is, after impregnation, suffered to graze on the usual pasture, being supplied, as occasion may require, with extra food, and especially in case of snow, until within five or six weeks of lambing, when turnips are given to her, and continued from that time until the spring of grass renders them no longer necessary. The turnips are laid out for the ewes in the grass fields in certain quantities each day, but by no means so many as they would consume if permitted to feed without restriction, as it is considered to be most important that they should not be too fat when the lambing season approaches. The hogs and the fattening sheep of the previous year, now one year and a half old, are put upon the turnips in October, or whenever the pastures cease to improve their condition. The turnips required for the cattle, or the ewe-flock, are then drawn off in alternate rows, in the proportion of one-half, one-third, or one-fourth, as the convenience of the situation, the goodness of the crop, or the quality of the land may dictate. The remainder are consumed on the ground by the other sheep.

As the period of parturition approaches, the attention of the shepherd should increase. There should be no *dogging* then, but the ewes should be driven to some sheltered inclosure, and there left as much as possible undisturbed. Should abortion take place with regard to any of them, although it does not spread through the flock as in cattle, yet the ewe should be immediately removed to another inclosure, and small doses of Epsom salts with gentian and ginger administered to her, no great quantity of nutritive food being allowed.

The ewes should now be moved as near home as convenience will permit, in order that they may be under the immediate observation of the lamber. The operation of *clatting*, or the removal of the hair from under the tail and around the udder, should be effected on every long-woolled ewe, otherwise the lamb may be prevented from sucking by means of the dirt which often accumulates there, and the lamber may not be able at all times to ascertain what ewes have actually lambed. The clatting before the approach of winter is a useless, cruel, and dangerous operation.

The period of lambing having actually commenced, the shepherd must be on the alert. The process of nature should be permitted quietly to take its course, unless the sufferings of the mother are unusually great, or the progress of the labour has been arrested during several hours. Experience will teach the course to be pursued in that case. If any of the newly-dropped lambs are weak, or scarcely able to stand, the shepherd must give them a little of the milk, which at these times he should always carry about him, or he must place them in some sheltered warm place; in the course of a little while the young one will probably be able to join its dam. The operation of castration should be performed nine or ten days after the birth of the lamb.

Unless the pasture on which the ewes are placed is very good, it will be advisable to continue the use of the turnips. A moderate quantity may be given twice in the day, care being taken that the whole of one quantity shall be eaten before any more is placed before them. This is a better practice than hurdling off certain portions of the field for the sheep, unless the land is perfectly dry. A little hay will always be serviceable while the flock is fed on turnips. It corrects the occasional watery quality of the turnips, and the sheep usually thrive better than if they are fed either on hay or turnips alone. Bran and oats, with oil-cake, have been recommended for the ewes before weaning time, but this is an expensive measure, and its cost can hardly be repaid either by the ewe or the lamb. By the end of March or the beginning of April the turnips are generally nearly consumed, and the farmer is occasionally a little puzzled to find sufficient food for his flock. He should have had some plots of rye to support them for awhile. Rye-grass and clover are very serviceable. Mangold wurzel and Swedish turnips that have been carefully stacked on dry straw will be most useful, for they will retain their nutritive quality until the flock can be conveniently supplied with other food.

At length comes the time for weaning. In a poor country it takes place before the lambs are much more than three months old. In a more plentiful one the lambs may be left until the fourth month is nearly or quite expired. If the pasture is good, and it is intended to sell the lambs in store condition, the weaning may be delayed until six months. Whichever time is selected, it is of essential consequence that the mothers and the lambs should be placed so far apart that they cannot hear the bleatings of each other. The ewes should be somewhat carefully looked after, and if any of them refuse to eat, they should be caught, the state of the udder ascertained, and proper measures adopted.

The lambs should not be put on too stimulating food. The pasture should be fresh and sweet, but not luxuriant. It should be sufficient to maintain and somewhat increase their condition, but not to produce any dangerous determination of blood to any part.

The Diseases of Sheep.—Commencing with the head, a parasite, having the appearance of a bladder filled with pellucid water, attacks the brain. The origin of it is connected with bad management, being scarcely known in upland pastures or in grounds that have been well drained. As the parasite grows, it presses upon the neighbouring substance of the brain, and interferes with the discharge of its functions; the sheep becomes giddy, is frightened at any trifling or imaginary object; he separates himself from his companions; he commences a strange rotatory motion even while he grazes, with the head always turned towards the same side. This is the characteristic symptom, and as soon as it is perceived the animal should be destroyed, for there is no certain cure, and many of the operations that some persons have described are cruel and inefficient.

A somewhat similar disease, but with which the hydatid has nothing to do, is *Hydrocephalus*, or *water in the head*, generally indicated by a little enlargement of the skull; a disinclination to move; a slight staggering in the walk; a stupidity of look, and a rapid loss of condition. This disease seldom admits of cure or palliation. If any amendment can be effected, it will be by the administration of good food, tonic medicine, and gentle aperients.

Another species of pressure on the brain is of too frequent occurrence —*Apoplexy.* A flock of sheep shall be in apparently as good and fine condition as the farmer can desire. They have for a considerable period grazed on the most luxuriant pasture, and are apparently in the highest state of health. By and bye, one or more of them is, without any previously observed change, suddenly taken ill. He staggers, is unconscious, falls and dies, and perhaps within a quarter of an hour from the first attack. With regard to how many over-fattened sheep is this the case? If there is time for resorting to curative means, the jugular vein should be opened, and aperient medicine administered.

Inflammation of the brain is a frequent consequence of over-feeding, It is ushered in by dullness and disinclination to move: but presently the eye brightens, and the animal attacks everything within his reach. If it can be managed, the same treatment must be adopted—bleeding, physic, and low feeding.

Hoove is a distension of the paunch with food, and the extrication of gas from that food. The hollow probang should be introduced into the stomach to draw off this gas. Four to five drachms of hartshorn in half-a-pint of water gives early relief to the animal.

There is however a disease of the liver—*the Rot*—far more frequently occurring in sheep than in cattle, and bearing a peculiar and more destructive character.

In the very earliest stage alone does it admit of cure. The decisive symptom, at that time, is a yellow colour of the eye that surrounds the pupil and the small veins of it, and particularly the corner of the eye, which is filled with a yellow serous fluid, and not with blood. There is no other apparent morbid appearance until it is too late to struggle with the malady; on the contrary, the sheep, although perhaps a little duller than usual, has an evident propensity to fatten. The rot is a disease of the liver—inflammation of that organ; and the vessels of it contain *flukes*. They are taken up in the food; they find their way to the liver as their destined residence, and they create or aggravate the disease by perpetuating a state of irritability and disorganisation. The rot is evidently connected with the state of the pasture. It is confined either to wet seasons or to the feeding on ground that is moist and marshy. In the same farm there are fields on which no sheep can be turned without getting the rot, and there are others that never give the rot. After long continued rains it is almost sure to appear. The disease may be communicated with extraordinary rapidity. A flock of sheep was halted by the side of a pond for the purpose of drinking: the time which they remained there was not more than a quarter of an hour, yet two hundred of them eventually died rotten. The fact is, they then received into their system the germs which ultimately assumed the destructive form of those flukes in the liver which destroyed them. In the treatment of the rot little that is satisfactory can be done. Some sheep have recovered, but the decided majority perish in despite of every effort. The patients however may, as giving them a little chance, be moved to the driest and soundest pastures, and there fed as liberally as possible; but, above all, plenty of salt should be placed within the animals' reach, and given to them in the way of medicine.

In the way of prevention the farmer may do much; he may drain the most suspicious parts of his farm. No money would be more profitably expended than in accomplishing this. Some of the little swampy spots which disgrace the appearance of his farm possibly lie at the root of the evil.

Redwater, or the effusion of a bloody serous fluid in the cavity of the abdomen, is a frequent and very fatal disease among sheep. The cause of it is a sudden change from one pasture to another of almost opposite quality, or the moving of the flock from a dry and warm to a damp and cold situation. It is most destructive to lambs if exposed to a hard frost or suffered to lie on a damp and cold soil. The sheep will separate himself from the rest of the flock; he will evince a great deal of pain by rolling about, and frequently lying down, and immediately getting up again; and, sometimes, he dies in less than twenty-four hours from the first attack. The belly will be found swelled and filled with the red water, or serous fluid tinged with blood, from which the disease derives its name. The treatment should consist of mild aperients, with gentian and ginger, and a liberal allowance of hay and corn.

Diarrhœa is a very prevalent disease among lambs, and especially after a change of diet or of situation. When it is not violent, and does not seem to be attended by colic, a little absorbent and astringent medicine, with a few grains of opium, may be administered. The diarrhœa of sheep may be similarly treated, but when the disease is assuming the character of *dysentery*—when the discharge is more frequent and copious, and mingled which mucus, a larger quantity of this medicine should be given, and some blood abstracted if there is any degree of fever.

The diseases of the *respiratory organs* are often of a serious character. During the greater part of the winter the nostrils will sometimes be filled with mucus, and the sheep is compelled to stop for a moment at every second or third bite, and snort violently, and stand with his muzzle extended and labouring for breath. If his general health does not seem to be affected, this will pass away as the spring approaches. If however any of the flock should now appear to be losing flesh and strength, it is too probable that *consumption* is at hand. The only chance of saving or doing them any good will be to place them in some comfortable pasture, letting them have ample food and salt within their reach.

Lambs, when too early and too much exposed, are subject to diseases of the upper air passages, one attended by a ringing cough, and the other by one of a more wheezing sound. Bleeding will always be necessary for the first, with aperient medicine. A mild purgative will usually suffice for the second, or possibly an ounce or an ounce and a half of common salt may be given dissolved in six ounces of lime-water.

Inflammation of the lungs, recognised by the difficulty of breathing, heaving at the flanks, and distressing cough, is a disease of frequent occurrence in sheep. It speedily runs its course, and the lungs are found to be one disorganised mass. Bleeding and purging are indispensable: but as soon as the violent symptoms seem to remit, tonics must follow.

Garget.—Inflammation of the udder is more frequent in the ewe than in the cow. The udder should be well fomented with warm water, and may then be returned to her lamb.

Diseases of the Feet.—The treatment of *foot-rot* essentially consists in paring away all loose and detached horn. This is the corner-stone of skilful and successful practice. All fungous granulations must either be cut away, or destroyed by the muriate of antimony, and the foot well washed with a solution of chloride of lime. The muriate of antimony must then be lightly applied over the whole of the denuded surface. This must be repeated daily until the whole of the foot is covered with new horn.

The Scab is a very troublesome disease, common in the spring and summer. The sheep is continually scratching himself with his feet, tearing off the wool, and violently rubbing himself against every protruding substance. It is a very infectious disease, for every place against which the sheep can rub himself becomes tainted with the poison. The sheep must be housed and shorn as closely as possible, and then well washed with warm water. An ointment composed of one part of mercurial ointment and seven of lard must then be procured, and such a quantity of it as the diseased parts seem to require rubbed in on every second day. Every place in the field and in the fold against which he can possibly have rubbed himself must be well cleaned and painted before he is permitted to return.

Lice and *Ticks* will be best got rid of by the application of the mercurial ointment just recommended.

The Fly.—Several species of fly frequently deposit their ova on the wool of the sheep. If there are any sore places, they are selected for the habitation of the larvæ. The head, as the most exposed part, is the one oftenest attacked, and the sheep are sadly tormented by the fly and the larvæ. The best preservative or cure is the application of a plaster composed of a pound of pitch and a quarter of an ounce of bees' wax, spread on soft leather or linen. The attack may however be generally prevented by the application of a small quantity of spirit of tar to the head, or any bare or sore part. Two or three applications of this will be sufficient for the whole of the summer, and not a fly will approach a sheep thus guarded.

WOOL AND THE WOOL TRADE. The term *wool* is now applied almost exclusively to the fleece of the sheep. The distinction between wool and hair is more easily understood than described. When the wool brought to bear in the comparison is that of sheep, the distinction is tolerably well marked; but in various other animals it seems often difficult to decide whether hair or wool be the proper appellation for the external covering; and hence perhaps the reason for the appropriation of the term wool principally to the coating of the sheep. Wool compared with hair is generally softer, more flexible, and more disposed to undergo the *felting* process, which imparts to it so much value in manufactures. Many of the wilder animals, such as the beaver, the racoon, the wild cat, and the otter, produce both hair and wool, the hair forming the long and conspicuous outer fibres, and the shorter fibres of wool lying hidden beneath. The goats of certain regions of Asia Minor, Tibet, and South America, yield woolly fibres of great beauty, which not only equal those of the sheep, but greatly surpass them; this wool, however, as we shall see farther on, is too costly to come prominently into competition with that of the sheep.

In a commercial and manufacturing point of view, a notice of wool may consistently be confined to that of the sheep; and for an account of the varieties of sheep, and of the wool they bear, as preliminary to the present article, we refer to the article WOOL, which immediately precedes.

The history of wool in its unmanufactured state, as regards the legislative enactments to which the commodity has been subjected, forms, however, a distinct subject, and is full of instruction in reference to the principles of commercial economy. It enables us to trace the gradual growth of just opinions on such matters, and the many conflicts by which these changes were wrought. Wool, as an article of wealth, has been singularly exposed to these contests; for the agriculturists and manufacturers for ages took different views of what measures in reference to the wool trade were for the national benefit, influenced perhaps by what they deemed their own interests. The reason lies in this circumstance: that whereas the silk and cotton manufacturers work upon materials brought wholly from abroad, the woollen manufacturer employs materials both of home and of foreign produce; and as this applies to foreign as well as to English manufacturers, there have arisen four distinct points upon which the legislature has from time to time had to decide, namely—the free exportation of British wool; the restrictions on such exportation; the free importation of foreign wool; and the restrictions on such importation. The reasons which have led the two great class interests to take opposite sides in the question, and the effects which that opposition has had on the wool trade, will be seen from the following brief details.

In the time of Edward I. a duty was imposed on the exportation of British wool; and great complaints were made on his increasing the duty in 1296 from 20*s.* to 40*s.* per bag. Lynn, Newcastle, Kingston-upon-Hull, Boston, Yarmouth, Ipswich, Southampton, Bristol, and

London were appointed ports from whence wool might be shipped, and at which customs' officers were authorised to receive the dues. When the king had terminated some of the wars in which he had been engaged, he lowered the duty from 40*s.* to half a mark per bag; but the high duty was again imposed at a subsequent period. In 1337 we hear of the first enactment for prohibiting the exportation of British wool, a measure coincident with the attempts of Edward III. to encourage the woollen manufacture in England. Subsequently the same king obtained grants of wool as the means of defraying the expenses of his wars; and the gross absurdity of his former restrictions could not be better shown than by the fact, that while he ostensibly prohibited the export of British wool, he sent his own quota for sale abroad, as he could there obtain a higher price for it than at home. Throughout the remainder of his reign Edward had frequent contests with the Commons and the merchants respecting his grants of wool, the duty payable on wool sold, and the prohibition to exportation; the contests being not between agriculturists and manufacturers, but between the king on one side and all his subjects on the other. By a statute of 27 Edw. III., the towns of Newcastle, York, Bristol, Lincoln, Norwich, Westminster, Canterbury, Chichester, Winchester, Exeter, Caermarthen, Dublin, Waterford, Cork, and Drogheda were appointed *staples* for wool; that is, places where alone wool could be sold. Mayors of the staple were appointed to seal every sack of wool sold; a customs' duty of half a mark per sack was charged to denizens, and of 10*s.* a sack to aliens; and the power of exporting was limited to merchant strangers, or to Hanse town merchants.

During the reigns of Richard II. and Henry IV. there were repeated grants or subsidies of wool to the king, petitions from towns concerning the places for the staple, alterations in the customs' duty, and licences granted to particular parties in respect of exportation. The same, indeed, may be said respecting the next two reigns; but by the time of Henry VI. the merchants of the staple appear to have acquired a kind of monopoly, which was often made a subject of complaint. Edward IV. enacted that no alien should export wool, and that denizens should export it only to Calais; and in the next three reigns the policy pursued, however mistaken, seems to have arisen rather from a hope of encouraging woollen manufactures in England than to fill the coffers of the king. In the reign of Edward VI., the landowners of England, finding the sale of wool profitable, began to inclose common lands as sheep pasturages with so much eagerness as to cause great complaints to be made; and this may perhaps be taken as the commencement of a new order of proceedings, so far as the cultivators took up a position really or apparently opposed to the interests of the people. It was not, however, till the time of Charles I. that the absolute prohibition of exportation was determined on seriously; and this seems to have been, in the first case, not so much a measure demanded by the manufacturers, as a source of revenue to the king by granting licences to favoured persons. After the Restoration, in 1660, however, the prohibition became distinctly enacted.

From 1660 to 1825, the export of wool was strictly prohibited. The consequences of this prohibition soon showed themselves. The wool-growers, shut out from a foreign market, suffered from diminution of price; all kinds of extravagant expedients were resorted to, to increase the consumption of wool; a system of wool-running, or smuggling, became very prevalent; and many pamphlets appeared from parties taking opposite sides of the question at issue. The agriculturists, thus restricted in respect to wool, insisted on the prohibition of the import of Irish cattle, as one means of maintaining their rents; this disturbed the course of trade between England and Ireland; and the attempts made, at the instigation of the woollen manufacturers, to compel the use of woollen goods, excited the hostility of the silk and linen trades; and thus the whole commercial system became disarranged. Numerous pamphlets were published in the last century, of the following general tenor: from English wool-growers, to show that Irish wool ought not to be imported into England; from English manufacturers, to show that Irish wool ought not to be sent to foreign countries; from Irish graziers, to show that both of these restrictions were unjust; and from foreigners, to show that the non-exportation of British wool led to retaliative measures on their part. The agricultural and manufacturing classes felt that they were by legislative measures thrown into antagonism; and there arose from time to time complaints on both sides. A slight sketch of what occurred in 1781 will convey a correct idea of the usual state of party feeling concerning the wool trade, for a period long subsequent, as well as long previous, to that date. The price of wool being low, meetings were held in Lincolnshire and elsewhere, under the auspices of the great landowners; at which petitions to parliament were agreed to, praying that British wool might be exported, and that Irish wool might be excluded from England. Thereupon the Yorkshire manufacturers met, and came to resolutions that the exportation of wool would be ruinous to the trade and manufacturers of England; that the manufacturers would be obliged to leave the kingdom for want of employment; and that the importation of Irish woollen yarn ought to be interdicted. The worsted manufacturers were particularly vehement, for they had a notion, whether correct or not, that no other country produced long combing or worsted wools equal to that of Lincolnshire; and that if they could keep the whole of this wool in England, they might perhaps retain a monopoly of the worsted trade.

The union with Ireland, in 1800, was another cause of disagreement in the wool trade. By one of the resolutions of parliament preparatory to that measure, it was determined that the two countries should be placed on an equality as regards bounties, prohibitions, &c., on the natural produce of each. One effect of this would be to legalise the transit of wool from England to Ireland; and the manufacturers in a body opposed it, but without success. Thus was effected one step in the attainment of increased power on the part of the English wool-growers; and another step was made in 1802, by the imposition of a duty of 5*s.* 3*d.* per cwt. on the importation of all foreign wool. This latter measure of course enhanced the comparative price of English wool. It had long been urged that foreign wool was indispensably necessary to the manufacture of some kinds of goods, and towards the end of the last century the imports became considerable. Year after year the quantity increased, and by 1800 it reached 4,000,000 lbs. in the year, being about $\frac{1}{25}$th part of the quantity required in the manufacture. This alarmed the landowners, who thereupon procured the imposition of a duty of 5*s.* 3*d.* At various times the leading agriculturists made laudable attempts to improve the quality of English wool, by introducing the Spanish merino sheep; but they still found that when their wools came into the market with those from Spain and Saxony, the latter, notwithstanding the import duty, commanded a more ready sale for the manufacture of the finer cloths. Hence an increase of the import duty was constantly urged upon the government, and such an increase was made to a small extent in 1813, by fixing the duty at 6*s.* 8*d.* instead of 5*s.* 3*d.* per cwt. But this not satisfying the landowners, renewed demands were made; and by the year 1816 parties were placed in a curious antagonism, which may be thus represented:—

Landowners' Claims.	Manufacturers' Claims.
Restricted imports of wool.	Unrestricted imports of wool.
Unrestricted exports „	Restricted exports „

The landowners wished to keep out foreign wool, that their own might command a higher price; and at the same time wished for an unrestricted foreign market for their own wool. The manufacturers, on the other hand, wished for a free import of foreign wool, because it was best adapted for their work; and at the same time wished to prevent the export of British wool, as a means of monopolising woollen manufactures. Each party argued consistently with liberal policy in one instance, but displayed the narrow spirit of monopoly in the other: there was a right and a wrong on each side—a liberal and an illiberal; and the two parties were so far pretty equally matched. In most of the subsequent measures taken by the two parties in reference to the wool trade, the peers and commoners belonging to Yorkshire generally took the manufacturers' view of the question; while those in the sheep-rearing counties took the opposite view; and petitions and resolutions were poured forth in abundance by both parties. In 1818 the matter was brought on in parliament by the agriculturists, and lost by only a very small majority; but in the following year the country was taken by surprise by a government proposition, which was carried by a large majority, to increase the import duty on foreign wool from 6*s.* 8*d.* to 56*s.* per cwt.

The depressed state of the woollen trade, partly consequent on this impolitic tax, was one of the moving causes to the disturbances in the north between 1819 and 1821; and the attention of the government was repeatedly directed to this matter by the opposite statements of different parties. In 1824, Mr. Robinson, after alluding to the peculiar tinge of monopoly shown in the arguments of both parties, proposed to admit the export of British wool at a duty of one penny per pound, and the import of foreign wool at an equal duty—thus showing to both parties the same meed of fairness. Neither party seemed very well pleased with the proposal; but ministers brought it before parliament, and carried it into a law. In the following year (1825), Mr. Huskisson carried some of his measures, which still further opened the woollen trade.

In 1828 the wool-growers induced the House of Lords to appoint a Committee of Inquiry; but the evidence taken before it appears to have convinced the government that it would be wrong policy to re-impose the import duty as a protective measure; and there has not since then been any renewal of the obnoxious duties.

Many of the legislative enactments here alluded to depend evidently on some peculiarity in foreign wool which fits it for manufacture; and this was strikingly illustrated in the evidence before the Lords' Committee, in 1828, where several eminent manufacturers stated that they could scarcely find a sale for any woollen cloths if made wholly of English wool. This led to many laudable efforts to improve the character of both our long and short-woolled sheep.

We will now briefly trace the progress of the wool-trade, in relation to the produce of English fleeces, and the importation of others from abroad.

In the year 1800 Mr. Luccock estimated the quantity of wool produced in England and Wales thus:—

Short wool	202,737	packs.
Long wool	181,794	„
Skin wool	58,705	„
	393,236	„

Mr. Hubbard's estimate for 1828 was—

Short wool	129,917 packs.
Long wool	263,847 "
Skin wool	69,405 "
	463,169 "

a pack being equal to 240 lbs. It has often been asserted that the attempts to improve the quality of English mutton has deteriorated the *quality* of the fine wool, but increased the *quantity* of the long wool; and this seems to be borne out by the numbers here given. Mr. Bischoff gives a table to show the quantity of foreign wool imported every year from 1741 to 1841. We will give a few of the years.

	lbs.		lbs.
1771	1,829,772	1811	4,739,972
1781	2,478,332	1821	9,770,103
1791	3,014,511	1831	31,652,029
1801	7,371,774	1841	49,710,396

These numbers sufficiently show how prone English woollen manufacture is, when left to itself, to derive aid from the use of foreign wool. All the finer wools used to be brought from Spain; but in 1765 the elector of Saxony imported into his dominions a few Merino sheep, which have had a most surprising influence on the trade in wool. The Saxony Merinos, instead of degenerating, improved upon their Spanish progenitors, and the wool afforded by them has almost driven the Spanish wool out of the English market. In 1800 the imports of wool from Spain were fourteen times as large as from Germany; whereas in 1840 those from Germany were seventeen times as large as those from Spain.

The inquiries made within the last twenty years, into the history of the wool-trade, present many points of interest. How many sheep there are grazing in the United Kingdom at one time, and how much wool is obtained from them, are matters on which no trustworthy figures have been given. All is guess-work. In 1860 Mr. P. L. Simmonds gave a curious comparison of estimates made at different times during the present century, relating, in most instances, to the number of sheep supposed to be living at one time, but more especially to the supposed weight of wool annually obtained from them. These estimates are eleven in number. The quantities, or round numbers, are as follows:—

Year.	Computer.	Sheep.	Wool.
1801	Luccock	26,000,000	94,000,000 lbs.
1828	Hubbard	?	111,000,000 "
1834	M'Culloch	32,000,000	? "
1835	M'Queen	48,000,000	247,000,000 "
1845	Low	35,000,000	157,000,000 "
1851	Southey	55,000,000	275,000,000 "
1852	Poole	32,000,000	128,000,000 "
1857	Ashworth	?	143,000,000 "
1858	Baines	?	200,000,000 "
1860	Wray	55,000,000	275,000,000 "
1860	Simmonds	50,000,000	250,000,000 "

Mr. Leonard Wray, in 1860, made an earnest attempt to arrive at the truth; the opinions expressed to him by wool-growers and wool-staplers were most discordant; but he arrived at a hypothetical result very similar to one which Mr. Southey had put forth in 1851. Mr. Simmonds has given a curious comparison of the wool-producing powers of various kinds of sheeps' food, only possible since the wide development of the study of agricultural chemistry. According to this comparison, equal weights of the following kinds of food will lead to the production of the following weights of wool:—

Potatoes, raw, with salt	6⅓ of wool.
Mangel-wurzel, raw	5¼ "
Wheat	14 "
Oats	10 "
Rye, with salt	14 "
Rye, without salt	12¼ "
Barley	12¼ "
Peas	16½ "
Buckwheat	10 "

Peas, wheat, and rye with salt, thus appear to be the best. What is the best *mutton*-producing food for sheep, as contrasted with *wool*-producing, we have no concern with here. There are six different qualities which manufacturers look for in wool—*fineness*, or equable thinness of fibre; *fullness*, or closeness in the growing of the locks on the sheep; *freeness*, or absence of entanglement in the fibres; *soundness*, or strength of fibre when pulled in combing; *length*, or a fitness in the length of fibre for each particular kind of manufacture; and *softness*, or a certain degree of silkiness to the touch. According to the degree in which wool possesses any or all of these qualities, so is the price which it will command in the market. During the latter half of the last century, English wool commanded from 6*d.* to 1*s.* 1*d.* per pound. During the first quarter of the present century, the price varied between the wide limits of 7*d.* and 3*s.* Since the freedom of import and export, the price has depended more consistently on the actual quality. While English wool, very little applicable to the manufacture of fine cloth, sells at 10*d.* or 1*s.* per pound, Saxony or Merino wool will often command 2*s.* to 4*s.* The good Saxony fleeces are always smaller in weight than the coarser English; the former varying from 2 lb. to 3 lb., the latter from 4 lb. to 5 lb. About half the home supply is used for worsted goods, and half for cheap woollens; the best woollens now depend wholly on the use of foreign wool.

One of the most notable present features in the wool trade is the competition of Australia. We have said that Germany nearly drove Spain out of the market; and now Australia is eclipsing Germany. It is found that the climate and soil of Australia, and the kind of labour obtainable, are favourable to the growth of wool. This has been done with very little encouragement from external sources.

Wool is largely imported from the British possessions in South Africa. India, it is believed, could easily supply us with 200,000,000 lbs. of wool annually, by the display of a little energy. Chinese sheep, brought to England and America, have proved very profitable, producing large fleeces of wool suitable for cheap goods. Australia could greatly increase her present supply, did not gold-digging frequently disturb the course of pastoral industry. The United States do not produce enough wool for their own manufactures; they import good wool from Europe, and cheap wool from South America. It affords a curious instance of the tendencies of trade when unshackled, that the United States' mills work up Australian wool which has come to them *viâ* England—a distance altogether equal to two-thirds of the circuit of the globe.

The total quantities of wool—whether sheeps', lambs', or Alpaca, imported in recent years, will conveniently be shown by taking certain dates, three years apart:—

	lbs.		lbs.
1843	49,243,093	1852	93,761,458
1846	65,255,462	1855	99,300,446
1849	76,768,647	1858	126,738,723

It will suffice to take one year, 1860, to show the trade a little more in detail:—

	lbs.
Wool from Australia	59,165,939
" Northern Europe	38,840,961
" East Indies	20,214,173
" South Africa	16,574,345
" Other countries	10,705,233
	145,500,651

Of this quantity, however, rather more then 30,000,000 lbs. were exported, leaving about 115,000,000 lbs. of foreign and colonial wool to be used up by our woollen and worsted manufacturers.

It will be desirable here to say a few words concerning the prospective supply of that peculiar kind of wool called *alpaca*. Under ALPACA WOOL it was stated that Australian sheep farmers were beginning to attend to this subject. We will here briefly notice what has been done since that article was written. It is to Mr. Charles Ledger that we owe most of what is known concerning the wool of the *alpaca*, *llama*, *vicuña*, and *guanaco*, animals which pasture on the high table-lands among the Andes. Those four kinds have slight differences; and by cross breeds between the animals it is believed that wool will be obtained of finer quality than any yet known. The Peruvians use llama wool for sacking, cordage, carpets, bed coverlets, &c., and alpaca wool for various textile fabrics. Mr. Outram, of Halifax, first overcame, in 1835, the difficulty of spinning alpaca wool by machinery; and Mr. Titus Salt, of Saltaire, made those further improvements which established alpaca among the staple manufactures of Yorkshire—especially when combined with cotton warp for strong but cheap goods, and with silk for waistcoatings and ladies' dresses. A demand having been thus created, the supply has gradually increased. Alpaca comes to England in small bales, from 60 lbs. to 150 lbs. each. 1835 was the first year of considerable import; it amounted to about 100,000 lbs.; this increased to 1,200,000 lbs. by 1845; and from 1851 to 1860 the imports averaged about 2,500,000 lbs. yearly. The price has fluctuated considerably, from 8*d.* to 3*s.* 9*d.* per lb.

Mr. Ledger, for many years a resident in Peru, conceived the idea of transferring alpacas to Australia, as a commercial speculation. In 1853 he went to Melbourne and Sydney, to ascertain whether the climate and soil of Australia were suitable for his purpose; and he found spots which possessed in an admirable degree all the requisite qualities. He returned to Peru and made arrangements for gradually buying and rearing a large stock of alpacas: undergoing great hardships while travelling repeatedly over the Andes. It was not until 1858 that he could get his flock into the Argentine States; for the government of Peru placed all kinds of obstacles in the way of their exportation. At length, in November 1858, a flock of 276 alpacas, llamas, and vicuñas arrived safely at Sidney. In May, 1859, he began a tour of inspection, at the instance of the New South Wales government, to select the best place for a breeding and pasture ground. He fixed on the Maneroo district, about 260 miles from Sidney. The first shearing, in November of that year, was too early, and the wool was pronounced in Yorkshire to be too short-stapled for the best goods. The flock was transferred to Maneroo; and the numbers are gradually increasing. Mr. Ledger has made a calculation that, allowing for accidents, deaths, bad years, &c., he very earnestly looks forward to

3000 alpacas by 1870; and if this estimate be borne out, the increase after that would be very rapid. The New South Wales government, regarding the subject as one of great colonial importance, have made liberal arrangements with Mr. Ledger; for Yorkshire will eagerly buy all the alpaca that Australia can produce; and especially will this be the case if the quality can be maintained at a high standard.

WOOLLEN AND WORSTED MANUFACTURES. The manufactures in wool and in worsted are so closely connected, in reference both to their past history and to the industrial arrangements involved in them, that it will be convenient to treat of them under one heading. Wools are divided into two great classes—*clothing-wools* and *combing-wools*, or *short-wools* and *long-wools*; and the fabrics woven from them are termed *woollens* or *worsteds*, according as the one or the other is employed. Clothing-wools possess in high perfection that peculiar property which enables the fibres to felt or interlace one among another, and to form thereby the dense compact material of which men's garments are so largely made in this country, as well as the still thicker felt for hats [Hat Manufacture]; whereas combing-wools, though long in fibre, are deficient in the felting property, and are therefore employed for stuffs, merinos, hosiery, and a large number of fabrics which do not undergo the felting or fulling process.

History.—It is probable that no other of the textile manufactures is so ancient as that of wool. Sheep were reared from the earliest times, and there can be little doubt that the use of the wool for clothing was soon adopted. If a mass of woollen fibres be pressed firmly together in a flat layer, the fibres, by virtue of their felting property, will cohere into a continuous sheet even without the process of weaving; and this property could not fail to attract notice. The passages in the Bible which seem to allude to the use of woollen garments are well known; and we have indirect evidence from various quarters to show the prevalence of a similar custom in the East generally, in early times. The spinning of the fibres was most probably effected by the fingers; while the thistle or teasle, as at present, was used to comb out the fibres; the dyeing of the threads, too, it is quite evident, was well understood by the ancients. Among the Greeks and Romans the woollen manufacture was of a domestic character; but yet it would seem that the clothing of large armies must have required arrangements of a more extensive kind. The natives of India, after the epoch of Macedonian conquests in that country, made shawl-cloths of exquisite beauty, consisting, as is supposed, of short wool woven without felting: and the Greeks and Romans may have derived some of their modes of proceeding from such a quarter. But however this may be, the Romans of both sexes wore woollen garments very generally.

The decay of the arts consequent on the irruption of the barbarians into Rome did not appear to have extended to this manufacture. Woollen clothing was still made in most of the countries where the Romans had established colonies; and there are indications that in the 10th century the manufacture became the occupation of a particular fraternity in the Low Countries. The wool employed was at first the produce of their own country; but they afterwards imported wool from other countries, and carried on the manufacture to such an extent that the Low Countries became in a great measure the clothing district for Europe. Spain produced cloth for herself, and acquired, about the 13th century, considerable reputation for the beauty of the fabrics produced, consequent, we may suppose, on the fine wool which the Spanish sheep have for centuries produced. The Italians and French entered upon this manufacture at a later period.

In the time of William the Conqueror, an inundation which occurred in the Netherlands drove many of the clothiers into other countries, and some of them came to England. William of Malmesbury says that the king, glad of such an accession, placed these Flemish clothiers first in Carlisle and then in the western counties. From that time the mention of clothiers is frequent in the old chronicles; London, Oxford, Lincoln, Huntingdon, York, Nottingham, and Winchester, being enumerated as towns wherein the manufacture was carried on; while at other towns there were cloth-dealers who paid a licence-duty to the king for the privilege of buying and selling dyed cloths. It has been stated [Wool and the Wool Trade] that the king frequently derived considerable revenues from English wool; and this circumstance led to the enactment of many laws, tending to the exclusion of foreign wool and the use of English wool only in our manufactures. The exclusion of Spanish wool from English broad-cloth; the limitation of the width of broad-cloth to two yards; the determination of the width of striped cloth made at Bristol; the appointment of towns where alone cloth could be bought and sold; the appointment of the office of king's *Aulnager*, whose duty it was to attend the cloth-markets, and measure all the cloth sold, to see that there was no deficiency of length, and who received a fee for every piece of cloth to which he attached his seal; the prohibition to export woollen cloths until they had been fulled; the granting of permission to make certain coarse kinds of cloth three-quarters of a yard in width; the fixing of a leaden seal to pieces of cloth wrought in London and the suburbs—these are some of the laws by which the government tried or hoped to regulate the manufacture; and they will serve to convey an idea of the general character of others.

Edward III. brought about a great extension of the manufacture by inviting over some skilful weavers from the Netherlands. English wool was said to be worked up more successfully in the Netherlands than in England; and Edward thought that by getting over some of the Flemings to this country, he could improve the native manufacture. This seems to have been done; and the following distribution of the manufacture, consequent on this immigration, shows how widely this branch of industry became spread—Norfolk, fustians; Suffolk, baize; Essex, says and serges; Kent, broad-cloth; Devon, kerseys; Gloucestershire, cloth; Worcestershire, cloth; Wales, friezes; Westmoreland, cloth; Yorkshire, cloth; Somersetshire, serges; Hampshire, Berkshire, and Sussex, cloth.

For several reigns subsequent to that of Edward III., the woollen cloths made in England appear to have been chiefly of a coarse quality; the majority of the manufacturers directing their attention chiefly to worsted fabrics; while the finer broad-cloths were imported from Brabant, a proof that the exertions of Edward, though successful as regards the extent of the manufacture, were not so in respect of quality. By the reign of Henry VIII. the exports of English cloths became very large, insomuch that when, through foreign wars, the markets of Spain and the Netherlands were closed to the English, great complaints arose among the manufacturers, who could not sell the cloth which they sent to Blackwell Hall, a kind of Cloth Hall whence London dealers and merchants were supplied. About this time the manufacture in the counties of Somerset, Gloucester, Wilts, and Worcester was limited to corporate towns; and the most absurd laws were passed to confine it to those favoured spots. During the reign of Elizabeth, owing partly to many of these restrictions being removed, and partly to the immigration into England of many weavers driven from the Netherlands by the persecutions of the duke of Alva, a considerable advance was made in the English manufacture. In the following reign the English dyers succeeded in obtaining a law prohibiting the export of cloth in the white or undyed state, under the expectation that they would be gainers thereby; but, like many other monopolies, it defeated its own aim; the Dutch and Germans refused to buy English cloth in the dyed state, and thus the exports fell so enormously that dyers as well as manufacturers lost by the impolitic prohibition.

During the time of the Stuarts a narrow policy almost ruined the manufacture. At one time there was an attempt to get all Spanish wool brought to this country, and to no other countries; at another time the exportation of English wool, of fuller's earth, and other materials of manufacture, was prohibited; English clothiers refused to receive Flemings among them, from a feeling of jealousy; the London merchants procured an act prohibiting all foreigners from buying and selling; and many other measures were passed, either by parliament or by corporations, tending to cripple the free spread of the trade and manufacture. Ireland suffered severely by this mischievous system; for after being compelled to give up the exportation of cattle to England, on account of the complaints of the graziers, she turned attention to the growth of wool; but this offended the English wool-growers; and if Irish cloths were sent to England, this roused the opposition of the English clothiers; so that from about 1640 to the end of the century there was one continuous struggle in Ireland to bear up against the selfish policy of England in respect to wool and its manufactures.

Throughout the greater part of the 18th century the manufacture steadily increased in England, especially in those fabrics made of long or combing wool. When the inventions in spinning-machinery gave an extraordinary impetus to the cotton-manufacture, that of woollen became thrown comparatively into the shade; but the application of improved machinery has since increased the power of the manufacturers; while the great improvements in the quality of German and Australian wools, combined with the maintenance of a liberal policy in commerce and interchange, have given to the woollen and worsted manufactures in England a more healthy tone.

Woollen Manufactures.—It has been before explained that the woollen manufacture relates to such fabrics as require the use of short or felting wool. This wool undergoes a very large number of processes in the course of the manufacture. If we take a piece of superfine broad-cloth as a representative of this manufacture generally, the following are the successive processes by which it is produced:—

1. Sorting the wool.
2. Scouring.
3. Washing.
4. Drying.
5. Dyeing (when dyed in the wool).
6. Willying.
7. Picking.
8. Oiling.
9. Moating.
10. Scribbling.
11. Plucking.
12. Carding.
13. Slubbing.
14. Spinning.
15. Reeling.
16. Warping.
17. Beaming.
18. Singeing.
19. Sizing.
20. Weaving.
21. Scouring.
22. Dyeing (when dyed in the cloth).
23. Burling.
24. Fulling.
25. Scouring.
26. Tentering.
27. Teazling.
28. Shearing.
29. Boiling.
30. Brushing.
31. Picking.
32. Pressing.
33. Steaming.
34. Packing.

More than one-half of these, in the most improved forms of proceeding, are effected by machinery.

The sorting of the wool is the first operation, and is one of much importance, since the quality of the cloth depends greatly on a due admixture of different kinds of wool. Each pack of wool contains many different qualities, according to the part of the fleece whence it was taken, and other circumstances; and much tact and discrimination are called for in the separation. The sorter has to make his selection in relation to the *fineness*, the *softness*, the *strength*, the *colour*, the *cleanness*, and the *weight* of the wool; and in reference to these qualities he separates the wool into many parcels, which receive the names of *prime*, *choice*, *super*, *head*, *downrights*, *seconds*, *fine abb*, *coarse abb*, *livery*, &c. The finest fibre is that of Spanish ewe, the mean diameter of which is $\frac{1}{1370}$ of an inch; while the coarsest is that of Wilts ewe, measuring $\frac{1}{500}$ of an inch. All woolly fibres are thicker at one end than the other; but the less the difference in that respect, the more valuable is the wool; and this is one of the favourable points in Merino wool.

When the proper kinds are selected, they are next *scoured* and *washed*, to free them from the grease which invariably attaches to them. The wool is soaked in an alkaline ley at a temperature of about 120°, rinsed with cold water, and passed between the rollers of a powerful press to free it from nearly all moisture.

If the cloth is dyed in the wool, that operation succeeds the scouring; but if dyed in the piece, many other processes intervene; and it depends a good deal on the kind of colour as to which plan is followed. Supposing the dyeing to be completed, however, the wool undergoes the process of *willying* or *willowing*, which is somewhat analogous to the *batting* or *scutching* in the cotton-manufacture; the object being to open and disentangle the locks of wool, and cleanse them from sandy and other loose impurities. One among many forms of willy is a kind of hollow truncated cone, having an axis running through its centre; on this axis are fixed three wheels of different diameters, bearing on their circumference four longitudinal bars studded with sharp spikes. The cone revolves with a rapidity of three or four hundred revolutions per minute, within an outer cylindrical casing, whose inner surface is armed with similar spikes. The machine is fed, by means of an endless apron, with wool, which enters at the small end of the cone, and travels to the larger end by virtue of the centrifugal force produced by the rotation. As it passes onwards between and among the spikes, it becomes opened and disentangled, the fibres of each lock separated, and the impurities detached. When the wool has reached the lower end of the cone, it passes into a receptacle where a fan is revolving with great rapidity, by which a current of air is generated sufficient to blow away all the dust mixed with the wool; while at the same time a kind of revolving cage distributes the wool in a flat equable layer or stratum. Thus the same machine disentangles the fibres, separates the impurities, blows away the dust, and lays the wool in a smooth sheet.

Some kinds of wool require willying more than once; but this is not the case with the finer qualities. There are however frequently some impurities which cannot be removed by the willy; and such are afterwards picked out by boys or women, called wool-moaters, or wool-pickers. A further opening of fibres results from the process of *scribbling*; but before this is effected, the wool undergoes that of *oiling*; it being spread out on a floor, sprinkled with olive-oil, and well beaten with staves. The *scribbling-machine* consists of several cylinders, on whose external surfaces are rows of teeth or wires. These are combined in a strong frame, and so fitted as just to touch and work against each other; the wires on one cylinder are bent in a direction contrary to those in the adjoining one; so that when all the cylinders are revolving, and wool is applied to the first one of the series by an endless apron, it is caught from tooth to tooth, carried rapidly from cylinder to cylinder, separated completely from all entanglement, and finally given forth in the shape of a delicate fleece or sheet. It becomes wound on a revolving roller, after having passed through the scribbling-machine; but when it leaves the carding-machine it presents the appearance of slender rods, cylinders, or pipes, which are called *cardings*.

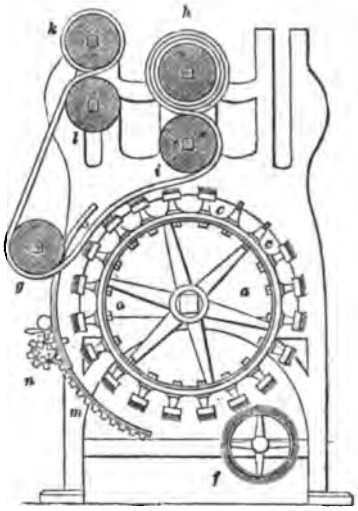
These cardings are then spun into yarn for the use of the woollen-weaver; the process of spinning being generally effected by means of the *slubbing-billy* or *slubbing-machine*, and afterwards by the common *jenny* or *mule-spinning* machine; the slubbing-billy bringing the wool to the state of a soft weak thread, and the spinning-machine giving it the proper firmness and hardness for yarn. The *slubbing-billy* has a wooden frame, within which is a moveable carriage, running on lower side-rails on friction-wheels. The carriage contains a number of steel spindles, which receive a rapid motion from a long cylinder, by means of separate cords passing round the pulleys of the respective spindles; this cylinder is a long drum of tin plate, six inches in diameter, covered with paper, and extends across the whole breadth of the carriage. The spindles are placed in a frame so as to stand nearly upright at about four inches apart; their lower ends being so formed as to act as pivots. The drum lies horizontally before the spindles, with its centre a little lower than the line of the spindle-pulleys. The drum receives motion by a pulley at one end with an endless band from a wheel placed on the outside of the main frame, turned by the spinner with his right hand applied to a winch; and by this movement the spindles are made to revolve rapidly. Each spindle receives a soft card or slubbing, which comes through beneath a wooden roller at one end of the frame. A child is employed here, who brings the cardings from the card-engine, and places them upon an inclined cloth. These cardings, being drawn beneath the roller, are then caught between two rails. The movement then is very similar to that in Hargreave's spinning-jenny; a small portion of each carding is allowed to pass between the rails or clasp; and this portion is then drawn out or elongated to the state of a thread by the recession of the carriage towards the other end of the frame. Meanwhile the spindles have been kept in motion, by which a slight twist is imparted to the thread or slubbing. A faller-wire and a rail assist in regulating the winding of the thread uniformly on the spindles. The process then is thus conducted. A child, called a *piecener*, takes the cardings from the carding-machine, and lays them on the inclined apron; they are thence carried up beneath the roller and between the clasp, and the workman or *slubber*, by managing his moveable carriage with one hand, and the wheel which turns the spindles with the other, elongates the *carding* into *slubbing*, and winds it on the spindles. The pieceners are employed and paid by the slubber; and some years ago great cruelty was said to be inflicted on the children by the workmen for any neglect of their duty; but the inspectorship of factories has removed such sources of discredit to the factory system.

In the *spinning* of the wool, which follows the slubbing, the kind of machines employed and the general character of the processes are so similar to those exhibited in the cotton manufacture, that it will suffice to refer to COTTON MANUFACTURE and SPINNING for details, with the following few additional remarks. The soft cord or sliver is caused to pass between two pairs of rollers; the space between the two pairs being rather more than equal to the length of the fibres. The two pairs of rollers between which the sliver is compressed do not separate farther from each other in order to stretch it, but that effect is produced by making the second pair of rollers revolve faster than the first. It is necessary to arrange the distance between the two pairs of rollers with reference to the average length of the filaments of which the sliver is composed; because if the two pairs of rollers were too far apart, the soft cord would be liable to separate between them, and if they were too near, so that the opposite ends of a filament should be compressed between them at the same time, the sliver could not extend or lengthen by the sliding of the filaments, but the filaments themselves must break with the strain. Hence, in machinery for spinning wool, on account of the variable length of the filaments, the drawing-rollers are so mounted that they may be readily adjusted to different distances. In consequence of the greater elasticity of wool, the relative velocities of the two pairs of rollers are so arranged as to produce a greater degree of stretching or extension than is usual with cotton.

The process next following that of spinning is *weaving*, by which the yarn is worked up into a textile fabric. If it be a plain cloth, the loom employed is very simple in its arrangements; if it be a twill or an ornamental fabric, the loom is somewhat more complex; but the general arrangements will be sufficiently understood by a reference to WEAVING. Hitherto woollen cloths have been principally woven by hand-weavers; but the power-loom is every year becoming more and more applied to this purpose. Some of the cloths are woven as broad as twelve-quarters, to allow not only for the shrinkage occasioned in the subsequent process of fulling, but for an edging or list, made either of goats' hair or of coarse yarn, into which the tenter-hooks are thrust in the process of *tentering*.

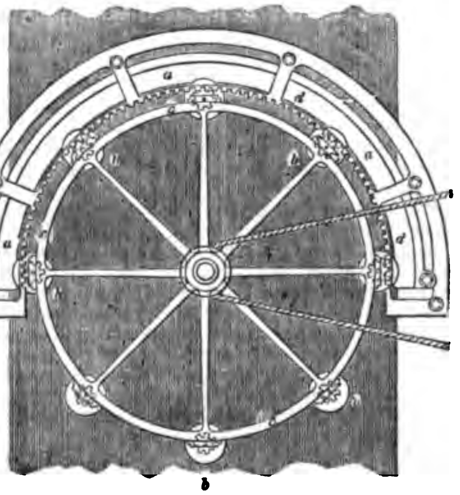
As the wool has been dressed with oil before spinning, and with size before weaving, it becomes necessary to cleanse it from these impurities immediately after the weaving. This is the object of a second *scouring* process, in which the cloth is beaten with wooden mallets in a kind of trough or mill; soap and water being let in upon it first, and then clear water. Being then carried to the drying-room, or the tenter-ground, it is stretched out by means of hooks on rails, and allowed to dry in a smooth and extended state. It is then taken into a room and examined by *burlers*, who pick out all irregular threads, hairs, or dirt. After this it is ready for the important process of *fulling*, or *felting*, which imparts to woollen goods that peculiarity of surface whereby they are distinguished from all others. A large mass of cloth folded into many plies is put into the *fulling-mill*, where it is exposed to the long-continued action of two heavy wooden mallets or stocks. Superfine cloth receives four fullings of three hours each, a thick solution of soap being spread between each layer of cloth every time. During the violent percussions which the cloth thus receives for twelve hours, the fibres, being at every stroke strongly impelled together, and driven into the closest possible contact, at length hook into each other by means of the little serrations on their surfaces, until they become firmly and inextricably united; each thread, both of the warp and weft, being so compacted with those that are contiguous to it, that the whole seems formed into one substance, not liable, like other woven goods, to unravel when cut with the scissors. This compacting process in the cloth manufacture is effected by beating, and is called *fulling*; in the hat-manufacture it is effected by pressure and rolling, and is called *felting*; but the two are clearly analogous in principle. This process thickens the cloth remarkably, but diminishes it both in length and breadth nearly one half.

In the fulled state the cloth presents a woolly and rough appearance, to improve which it goes through the processes of *teasling* or *raising*, and *shearing* or *cutting*. The object of the first is to raise the ends of the fibres above the surface, and of the second to cut them off to a uniform level. The raising of the fibres is effected by thistle-heads, teazling-cards, or wire brushes. Teazles are the seed-pods of the *dipsacus follonum*, having small hooked points on their surfaces. They were formerly used in the cloth manufacture thus: a number of them were put into a small frame with handles, so as to form a kind of curry-comb; and this was worked by two men over the surface of the cloth, which was suspended horizontally, the direction of working being first parallel with the warp, and then parallel with the weft. From the trouble required to clean the barbs of the teazles when filled with woollen fibres, from the weakening of their points by the water with which the cloth was saturated, and from the high price which the large demand enabled them to command in the market, numerous attempts were made from time to time to substitute metallic points; but from various causes the teazles are still preferred, and are now used in a more efficacious way than formerly. The teazles are arranged on a cylinder in a machine called a *gig-mill;* the cloth is stretched on two cloth-beams; the cylinder moves in one direction and the cloth in another, and the fibres become thereby worked or combed up. The annexed cut shows the section of such a machine; where the cloth, passing from a roller *h*, round the roller *i*, comes in contact with the brushes *c* on the wheel *a*, and afterwards passes round *g* and *l* to the roller *k;* the roller *g* being so regulated by the pinion *n* and the rack *m* as to keep the cloth thoroughly stretched; and the revolving brush *f* being so adjusted as to clean the teazling-cards *c*. In some machines the teazling-points are made of wire, to obviate the waste of 3000 natural teazles, which takes place in the dressing of one piece of cloth.



Gig-Mill.

When the ends of the fibres have been thus raised to the surface, they are next *sheared* or *cropped*, a process of great beauty and singularity. Originally this process was performed by means of large hand-shears, the cloth being stretched over a stuffed table, and the werkman proceeding to clip the ends of the fibres in a regular and equable manner. This was an operation requiring great dexterity; and the men who worked at it being in the receipt of good wages, were so alarmed at the introduction of shearing-machines, in the early part of the present century, that serious riots occurred in the west of England.



Cloth-shearing Machine.

But the machines became by degrees extensively employed. They consisted each of a pair of shears, as in the hand-method; but all the movements were effected by machinery. More recently a machine has been introduced, the action of which is regulated on a different principle, as will be seen from the annexed cut: *b b b* are disk-formed cutters, working against a thin bar of steel, *a a a*, of a semicircular form; which cutters in their revolution travel round against the edge of the bar or blade in such a way as to shave off the filaments standing up on the surface of the cloth beneath. The cloth is represented by the shaded part. The wheel *c c c*, set in motion by machinery, imparts action to the circular cutters attached to it through the medium of the rack *d d*. It is easy to see that, whether the machine travels along over the cloth, or the cloth travels along beneath the machine, every part of the fibrous surface is acted upon in precisely the same way by the double rotation of the wheel and the disk-cutters. There are other shearing machines in use, of equal ingenuity.

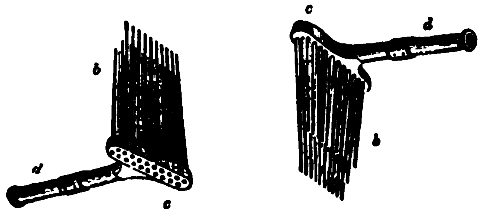
When the cloth has been raised and sheared (which operations are repeated two or three times for superfine cloth), it is *brushed* by a machine consisting of a system of brushes affixed to cylinders; the cloth being exposed at the same time to the action of the brushes and of steam. A few subsequent operations are carried on, having for their object the imparting of smoothness, gloss, &c. to the cloth, preparatory to its being placed in the hands of the dealers.

We have described most of the manufacturing operations in their simpler forms, for more ready comprehension; but it is well to bear in mind that new machines and new processes are being continually brought into this department of industry. A meeting of Leeds woollen manufacturers took place in 1860, to examine a new French machine invented by MM. Tavernier and Vouillon, "to convert slivers or rovings, as they came from the carding-engine, into threads suitable for weaving, by felting and friction, without any spinning process." It was declared that "many gold medals had been awarded in France for the invention; that many of the machines were at work; that no oil or size is necessary as a dressing; and that 30 per cent. of wool is saved." So far as we are aware, this favourable description failed to make the intended impression on the manufacturers. Many of the recent novelties in the trade relate to the employment of cotton for warp-threads, and of rag-wool mixed with new wool for weft; a subject briefly noticed under SHODDY MANUFACTURE. One inventor has brought into use a machine called a *combiner*, by which, when attached to the carding-engine, the wool is brought off in a continuous sliver wound on cylinders, ready to be conveyed to the spinning-machine. Mr. Archibald, of Tillicoultry, in 1858, introduced a machine for piecing the lengths of carded wool as they leave the carding-engine, and forming them into a continuous length or roving; the rolls drop into reversing channels, and thence to travelling belts, which convey them to a machine where they are connected into a length more uniformly than in the ordinary way. Without noticing the almost numberless new machines and processes, we may just mention a very curious process, patented by Messrs. Tolson and Irving, for imparting a metallic lustre to fine woollen cloth. The cloth, either in the yarn or when woven, is steeped in a solution of sulphate or oxide of copper, lead, or bismuth, and then exposed to steam charged with sulphuretted hydrogen gas, by which a metallic deposition takes place.

Other matters relating to the manufacture of woollen cloth will come under notice presently.

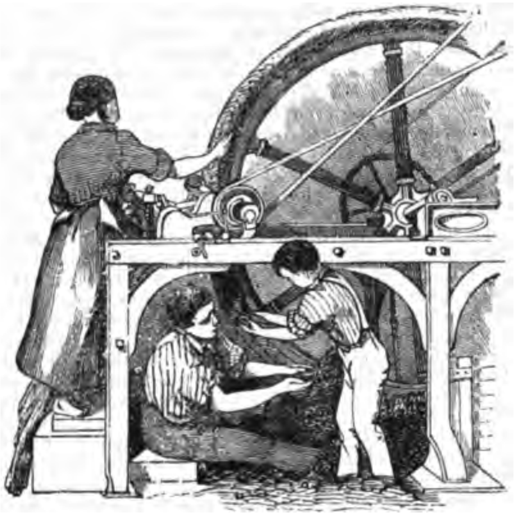
Worsted or Stuff Manufacture.—The long wools for worsted fabrics, not being felted or fulled, pass through a series of operations different from those hitherto noticed; since the object in view is rather to lay the fibres in a parallel position than to twist and entangle them one among another. All combing-wools are longer in fibre than the clothing-wools, but they are subject to the division into *long* and *short* combing wools; the long, varying from six to twelve inches in length, being used principally for coarse worsted goods; and the short, from four to seven inches, being used for hosiery and some other purposes.

After the wool has been *sorted, washed*, and *scoured* from the adherent grease, and *dried* in a heated room, it is carried to a machine called a *plucker*, containing a pair of spiked rollers, by the action of which the wool is cleansed, separated, and the fibres straightened, preparatory to the process of combing. In *hand-combing*, which, until modern times, was the only mode followed, and which is rather laborious work, the proceedings are somewhat as follow:—The comber is provided with a pair of combs such as are here represented, a comb-post to which to attach the combs, and a comb-pot or stove for heating the



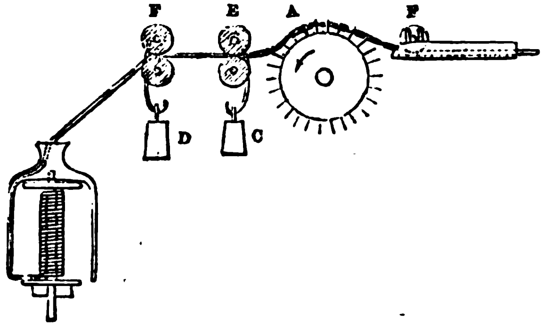
Wool-Combs.

teeth. Each comb consists of two or three rows of steel teeth, *b*, one row longer than the other, inserted in a wooden stock or head, *c*, from which protrudes a handle, *d*, at right angles to the direction of the teeth. The workman first heats the teeth of one of the combs in the stove, and fixes it in the post, teeth uppermost. He then takes a small handful of wool, consisting of about four ounces, sprinkles it with oil to increase the pliancy and ductility of the filaments, and works it about between his hands to equalise the oil on every part of the fibres. The comber then takes half the bundle of oiled wool, and dashes it on the upturned teeth of the comb, till it is all deposited there, and caught between the teeth sufficiently firm to be retained. The comb with its wool is placed, points downwards, in the stove; and the comber next fixes the other heated comb in the comb-post, lays the other half of the bundle of wool on it, and places this likewise in the stove. When both combs with their supply of wool are properly warmed, the comber holds one of them over his knee with his left hand, while seated on a low stool, and with the other comb, held in his right hand, he combs the wool upon the first, by introducing the points of the teeth of one comb into the wool contained in the other, and drawing them through it. This is repeated till the fibres are laid parallel. The wool which remains uncombed on the teeth, and which constitutes about one-eighth of the length of the fibres, is unfit for spinning into worsted, and is consequently applied to other purposes. In *machine combing*, the apparatus sometimes consists of two wheels of large diameter, like the one here sketched, having wires placed round the circumference, parallel with the axis, and pointed at one end so as to act like teeth. A boy, sitting on the ground, strikes wool on the points of the teeth in one wheel, so as to make it adhere to and between them. The two wheels are then made to rotate, the distance between them being such that the teeth of the one can draw through or comb the wool lying on the teeth of the other. This is effected with great rapidity; and when the combing is completed, the *top* or combed worsted is taken off by a boy or girl in a continuous sliver from the upper part of the wheel, while the *noils* or uncombed part is removed by another boy.



Combing-Wheel.

When the wool has been combed either by hand or machine, it is transferred to the *breaking-frame*, the object of which is to open out any fibres which may have escaped the action of the combs. In this machine the wool, after passing between rollers, is exposed to the action of a kind of endless comb, travelling round two rollers distant from each other; and the arrangements as to relative velocities are such, that the wool becomes somewhat drawn out as well as combed parallel, and leaves the machine in the form of a roll or narrow belt. The sliver of wool proceeds to a large bobbin or cylinder, round which it is lapped into a continuous roll. It is then passed a second time through a breaking-frame, having teeth finer and more closely set than the former. The soft woolly riband is then subjected to the action of a machine analogous in principle to the *drawing-frame* of the cotton manufacture; the object being to extend the length, diminish the thickness, and equalise the number of fibres of the sliver. Hitherto the woolly fibres are merely slightly coherent, without having any twist; but they are now passed through a *roving-machine*, preparatory to the process of spinning. The working parts of this machine are slightly shown in section in the annexed cut. The wool-carding or sliver passes beneath a roller F, towards a cylinder E, the surface of which is studded with points or teeth. The wool, after being acted on by these teeth, passes between the pair of rollers A, where it is pressed by the upper roller being urged downwards by the weight C. Of these rollers the upper one is of wood covered with leather, and the under one of iron, fluted parallel with the axis; and the rollers being made to rotate faster than the feeding-roller F, it necessarily follows that the sliver of wool becomes elongated to a state of still greater tenuity while passing between them. It is then caught by a second pair of rollers B, kept in close contact by the weight D; and as these rotate still more rapidly than the former, the sliver is still more elongated, until its thickness is so small that the fibres can scarcely cohere. But in order to give them the requisite coherent strength, they are slightly twisted by the bobbin and fly G, that beautiful contrivance which is so extensively adopted in the textile manufactures. One fork or leg of the rotating flyer G is hollow or tubular, and down this tube the delicate cord of wool passes; then, by the rapid rotation of the flyer, the wool or *roving* becomes wound on the spindle of the bobbin concentric with the flyer. The straight or rectilinear motion of the roving while approaching the flyer, combined with the circular motion at the flyer itself, imparts a twist to the roving, sufficient to enable it to undergo the process of spinning.



Roving-Machine.

The spinning of the worsted bears so close a resemblance to that of cotton, as described in Cotton Manufacture, and Spinning, that a reference to those articles will suffice to convey a general notion of the process. When spun, the worsted yarn is wound on a reel, and is thence made up into hanks of 560 yards each. These hanks receive denominations according to the number of them which go to a pound, and the yarn derives its name in like manner: thus, No. 24 yarn has 24 hanks to the pound. In some instances the hank is reckoned at 840 yards. The hanks are tied up into pounds; the pounds are combined into bundles; and the bundles are made up into bales of 240 lbs. each, ready for the market.

Here terminate the operations of a worsted-mill; for the dyeing of the yarn, and the weaving into the various kinds of textile fabric, lead us to other departments of industry. [Dyeing; Weaving.]

The worsted manufacture, like that of woollen, has been marked by the introduction of many new machines and processes within the last few years. Two or three of these may be briefly noticed. English wool is becoming less and less fitted for cloths, and more and more fitted for worsteds. Moreover, a length of staple, necessary under the old process of combing, is less needed under the modern. From both of these causes any kind of English wool, from three-inch staple upwards, is rendered available for one or other of the numerous kinds of worsted manufactures. Carding-machines in great variety have been adopted; and the chief inventor, Mr. Lister, made an attempt in 1855 to overturn the patent-claims for many of them, but failed in a court of law. Messrs. Croft and Steel's machine, introduced at Keighley in 1857, has a number of combs, each forming a circular segment; they are fixed to the outer ends of radiating arms carried by a horizontal disc, which rotates on a vertical axis. The combs, while rotating, pass in front of a feeding apparatus, and have a peculiar combing motion given to them by means of cranks; they advance and retire, rise and fall, and rotate, all at once. Each comb takes its proper quantity of wool from the feeder, and carries it round to the drawing-off roller. There are circular brushes to clean each comb after its passage, and a hot chamber in which the teeth are warmed. The great increase in the facility of machine-combing has been one cause of the more rapid advance of the worsted than of the woollen manufacture. Another is, that the fly-spindles, which so late as 1848 only made 2800 revolutions per minute, are now driven at the enormous velocity of 6000 revolutions. Another is, that while woollen cloth, from its great width (often 9 feet before being milled), cannot be woven at more than about 50 picks of the shuttle per minute, worsted weaving is often conducted at the rate of 160 picks. So great is the facility now offered for the use of cotton in mixed goods, or stuffs and worsteds, that out of 100 pieces of all kinds, taken indiscriminately from those produced in the Bradford district, it is estimated 95 have cotton warps; while the total weight of the whole produce is supposed to be two-thirds wool and one-third cotton. One of the curious novelties of recent years is Messrs. Saunders and Smith's process for utilising the *grease* resulting from the various scourings and washings to which the wool is subjected. Iron pipes convey the greasy water to a tank, whence a pump draws it up to other tanks, where it is heated by steam to 160° Fahr. Certain chemical substances are added, by which the creamy sud is converted into a scum and a sediment, with a liquor between them. The liquor is drawn off as useless. The scum and the sediment, nearly alike in composition, are drained in bags of matting, pressed forcibly, and made to yield an oily fluid. The fluid is used in making stearine, soap, and other saleable chemicals, while the refuse oil-cake is sold as manure. The patentees supply all the additional apparatus, besides buying the greasy wash at a stated price. *Creash*, or wool-waste so saturated with oil as to contain more oil than wool, is eagerly bought up by farmers as a powerful manure.

Localities and Varieties of the Trade.—When it is considered that woollen and worsted goods differ primarily in the length of fibre, it is easy to imagine that many varieties may be produced, according to the extent to which this separation is carried out. The various modes too in which the warp and weft threads are made to interlace, as explained in Weaving, naturally lead to the production of many different classes of goods. These four conditions, namely, the length of fibre, the application or not of the felting quality, the production or not of a velvet-like nap or pile, and the diversities depending on the loom, give rise to innumerable and fancifully-named kinds of woollen and worsted goods. Blankets, flannels, stuffs, merinos, mousseline-de-laines, bombazines, tammies, shalloons, says, moreens, calimancoes, camlets, lastings, baize, and a host of other names, some of which are now nearly or quite out of use, or are giving way to others, point to the diverse applications of long-wool in the production of woven fabrics; while kerseymere and other names indicate distinctions in the felted-wool goods. But besides these diversities, there are others depending on various circumstances; such as the admixture of woollen with worsted, or of either of them with cotton or silk, in the same fabric; the dyeing of the material, sometimes in the piece, sometimes uniformly in the yarn, and sometimes in a party-coloured mode called *clouding;* and the printing of devices on one surface.

A few examples may suffice to illustrate this diversity. Plain *broad-cloth* is a specimen of plain weaving, followed by the fulling process; whereas *kerseymere* is a twilled fabric, similarly fulled. *Serges* are twills, having worsted warp and coarse woollen weft. *Blankets* are made of very soft yarn, afterwards worked up into a kind of pile by milling; and many varieties of coarse cloth are of analogous structure. *Bombazeen* is a twilled mixture of worsted and silk; whereas *Poplin* is an untwilled mixture, showing more silk than worsted at the surface. *Saxonies* and *Orleans* are made of wool, sometimes mixed with cotton, and afterwards printed. *Stuff* is made wholly of worsted; while *Merino* is a fine woollen twill, sometimes printed. The material called *Cashmere*, if properly so named, is made of the shawl-goat wool, much in the same way as merino; but most of the fabrics so called are made of sheep's wool. *Challis* is a mixture of woollen weft with silk warp, and is generally printed. *Mousseline-de-laine* was originally all wool, but is now frequently mixed with cotton, and generally printed. *Norwich crape*, unlike common crape, is composed of wool and silk, something like challis, but without being printed. *Crêpe de Lyon* is formed of worsted and silk; and *Italian net* of worsted only. In *Waistcoatings*, fancy-weaving adds another to the sources of diversity. Many of the above kinds are briefly described under their proper names in this Cyclopædia; while a number of additional kinds will be found noticed under Shoddy Manufacture.

The West Riding of Yorkshire, the most important clothing-district in England, exhibits an area of nearly 40 miles by 20 occupied by clothing towns and villages. Leeds, Bradford, Halifax, Huddersfield, Dewsbury, and Wakefield are the great manufacturing centres. Mixed or coloured cloths are made principally in the villages west of Leeds and of Wakefield; white or undyed cloths are made chiefly in the villages occupying a belt of country extending from near Wakefield to Shipley. Flannels and baizes are the principal woollen articles made in and near Halifax, together with army cloth. Blankets are made on the line between Leeds and Huddersfield. Bradford provides very largely the spun worsted required for the various manufactures. Stuffs are made at Bradford, Halifax, and Leeds; and narrow cloths at Huddersfield. Saddleworth furnishes broad-cloth and kerseymeres. In the neighbourhood of Batley and Dewsbury are the shoddy mills. The West of England takes rank next to Yorkshire, and formerly took precedence of it. The finest kinds of broad-cloth, from Saxony, Australia, and Spanish wool, are made in Gloucestershire. The manufacture is carried on in a district called the *Bottoms*, and in other parts of the country; the town of Stroud being a kind of centre for the whole. Wiltshire produces very fine cloths, at Bradford, Trowbridge, Westbury, Melksham, Chippenham, and the surrounding villages; while cloth of various kinds is made at Wilton, Warminster, Heytesbury, and Calne. Taunton, Frome, Tiverton, and the surrounding villages constitute the Somersetshire clothing district. Devonshire and Dorset have little woollen manufacture. The Norfolk district was long the principal seat of the stuff or worsted manufacture. Bombazeens, crapes, camlets, and shawls have constituted the chief fabrics for which Norfolk has been celebrated. These are the three great English districts engaged in the consumption of wool; to which may be added Leicestershire, where nearly all the worsted stockings are made. It must be noted, however, that Yorkshire, with its abundant machinery and cheap coal, is every year absorbing a larger and larger proportion of the whole manufacture. In Wales the principal manufactures relating to wool and worsted are strong webs or high-country cloths, small webs or low-country cloths, flannels, stockings, socks, wigs, and gloves; the chief counties being Montgomery, Merioneth, and Denbigh. The strong webs are used principally for workmen's jackets, ironing cloths, &c.; while the small webs are largely used for slaves' clothing in the West Indies. In Scotland the fine woollen manufacture is upon a very limited scale; but a good deal is done at Aberdeen, Stirling, Galashiels, Jedburgh, Hawick, Inverness, Kilmarnock, and Paisley, in the production of various kinds of woollen and worsted goods, such as coarse plaiding, clan-tartans, woollen-hose, blankets, flannels, and especially carpets and shawls. The manufactures of woollen and worsted goods in Ireland are small in extent.

Different usages prevail in different counties respecting the connection between employers and employed, buyers and sellers, in the woollen and worsted manufactures. In the West of England the general plan of operation is this:—The master-clothier buys his foreign wool from the importer, and his English wool from the wool-stapler. He employs in all the different processes through which the wool passes in the course of manufacture, distinct classes of persons, who sometimes work at their own houses, and sometimes in the factory of the master-clothier. Each workman confines himself exclusively to a particular branch of the manufacture; and this has been supposed to have led to the excellence of the West of England cloth.

A second mode is on the factory system, now extensively adopted in the West Riding of Yorkshire. The master-manufacturer, who generally possesses a large amount of capital, employs a great number of workmen in one or more buildings, under the inspection of himself or a superintendent. In this system, as in the master-clothier system, the workman has no property in the material on which he is employed.

In the domestic system, which was the one originally adopted, the arrangement is altogether different. Under this system the manufacture is conducted by a number of small masters, who are generally possessed of very limited capital, and who, besides their business as manufacturers, mostly occupy farms of a few acres, partly for the support of their families, and partly for the convenience of their manufacture. The domestic clothiers have in their houses from one to four looms, on which they employ themselves, their wives, and children, and perhaps other assistants. During harvest their wives, children, and servants are sent out into the fields to work. Formerly these clothiers used to carry the wool through all the stages of its manufacture, till it was brought to the state of undressed cloth; but of late years they have availed themselves of public mills, which are established in and among the clothing-villages, for the performance of some of the processes. These mills have been erected on a joint-stock principle, by shares of 50*l.* or 100*l.* each, principally subscribed by the domestic clothiers. When machinery began to be extensively employed in the woollen manufacture, in the early part of the present century, the domestic clothiers became violently excited, under the apprehension that their trade would be taken from them by the newly-invented machines. A parliamentary committee was appointed to inquire into the probable operation of machinery in respect to the well-being of the domestic clothiers: and after examining numerous witnesses they made a report, in which they detailed the distinctive features of the factory and the domestic systems, and came to a conclusion that "the two systems, instead of rivalling, are mutual aids to each other; each supplying the other's defects, and promoting the other's prosperity." "Experience," says Mr. M'Culloch, "has proved the correctness of these conclusions. The number of small manufacturers, and the quantity of cloth produced by them, have both increased since 1806; but, as the number of factories, and the quantity of cloth made in them, have increased still more rapidly, the former constitute, at present, a less proportion of the trade." One circumstance which has enabled the domestic system to maintain its ground, is, that the great width of woollen cloth has been a difficulty in the way of power-loom weaving; the hand-loom cannot compete with steam in the stuff trade, but it can in broad-cloth. The domestic system would nevertheless have succumbed, had not the clothiers prudently adopted the joint-stock principle for their mills. Each shareholder takes his own wool to the mill to be cleaned, dyed, carded, and spun; brings it home to weave by himself and family; takes it to the mill to be fulled, washed, and tentered; and sells it at the cloth halls to merchants who employ dressers to finish it.

As respects the *sale* of the cloth, halls have been established for this purpose at Leeds, Halifax, Bradford, Huddersfield, and other towns, which are attended on the public market-days by thousands of the smaller class of manufacturers. The halls are divided into long walks or galleries, consisting of rows of stands, each of which is marked with the name of the person by whom it is occupied. On these stands the cloth is exposed for sale; and when the market opens, the manufacturers take their stations at the stands behind their goods, the merchants or buyers passing, to make their purchasers, through the avenues between the rows. The time during which the halls are open is limited usually to about one hour and a half; but in this short interval purchases to a very large amount are made. The cloth-halls at Leeds are appropriated exclusively to the use of those who have served regular apprenticeship to the business of cloth-making. They are managed by trustees, and many of the stalls are the freehold property of the persons who occupy them. All the cloth sold in the halls is rough and undressed. Those by or for whom it is bought have what are termed finishing-shops, where the cloth is shorn, dressed, and fitted for use. This is analogous to a system pursued by the bobbin-net manufacturers at Nottingham, where the net is sold by the maker in the rough state as it leaves the loom, and purchased by other parties, who singe, dress, and finish it ready for the market.

Statistics of the Trade.—In 1739, the writer of a pamphlet on the subject of wool estimated the number of persons engaged in the woollen manufacture at 1,500,000, and their wages at 11,737,500*l.* per annum. This estimate was obviously an overcharged one. Dr. Campbell, in 1774, thought that there might probably at that time be 1,000,000 persons employed in the manufacture in England; that the value of the wool used was 3,000,000*l.* per annum; and that this value was increased to 12,000,000*l.* by the processes of manufacture. In 1800 the woollen manufacturers, in committee before the House of Lords, made the extravagant estimate that there were then 1,500,000 persons directly engaged in the manufacture; that an equal number were collaterally employed in it; that the value of the wool used was more than 6,000,000*l.* sterling; and that of the manufactured goods nearly 20,000,000*l.* sterling. In 1815 Mr. Stevenson supposed that there were half a million persons employed, receiving 9,600,000*l.* per annum wages; and that this sum, added to the value of the raw material, the interest on capital, the manufacturer's profit, &c., gave 18,000,000*l.* as the annual value of the cloth produced. Mr. M'Culloch ('Statistical Account') forms an estimate on the following data:—That there are about 150,000,000 lbs. of wool worked up yearly; that this may be worth about 7,500,000*l.*; that the value of the manufactured goods is three times that of the raw wool, making therefore 22,500,000*l.* per annum; that this value is thus made up:—

Raw material	£7,500,000
Oil, soap, dye-stuffs, &c.	1,600,000
Interest, profit, &c.	4,650,000
Wages	8,750,000
	£22,500,000

And dividing this amount of wages at the rate of 26*l.* a year to each operative on an average, he arrives at the number 334,600, which he thinks a probable approximation to the number of persons employed in the woollen manufacture in this country. Mr. Chapman (one of the Assistant Hand-Loom Commissioners) made an estimate which agrees pretty nearly with that of Mr. M'Culloch; although at the first glance the two estimates seem discordant. He thinks that, in 1831, the number of families directly dependent on the manufacture were—

In the West Riding of Yorkshire	85,096
In the West of England	20,851
In Norfolk and Kendal	17,570
In the hosiery district	20,464
In all other places	20,000
	163,981

Then, taking the average number of persons in a family at 5¼, he arrives at an aggregate of 874,565 persons directly supported thereby. He further supposes that this number must have increased, by 1841, to 226,298 families, or 1,218,424 individuals. Mr. M'Culloch's estimate is of the number of persons *employed*, while Mr. Chapman's is of the number of persons *supported*; and this may explain the apparent discrepancy between the two estimates. As to the value of the manufacture, Mr. Chapman proceeds thus:—226,298 families, earning, on an average, 17*s.* 6*d.* per week each family, which amounts to 10,296,559*l.*; and the relation between this and the other items of the cost he thus states:—

Value of wool employed	£10,000,000
Oil, dye-stuffs, soap, &c.	1,500,000
Wages	10,296,559
Wear and tear, profit	4,359,311
	£26,155,870

In the last edition of his 'Commercial Dictionary,' Mr. M'Culloch makes an estimate, which he supposes to approximate pretty nearly to the true figures for the year 1858. He takes the consumption of English wool at 110 million lbs. at 1*s.* 3*d.* per lb., and that of foreign at 60 million lbs. at 2*s.* Then he makes up four large items thus:—

Wool	£12,875,000
Wages	7,725,000
Soap, oil, dyes, &c.	1,200,000
Profit, interest, wear and tear	4,200,000
	£26,000,000

Besides 2,000,000*l.* worth of shoddy and mungo manufactures. So far as regards woollen and worsted mills, and the persons engaged in them, see Factories. Some writers have guessed the total value at 50,000,000*l.*; but this is only a guess. At a recent period, in a woollen factory at Leeds, 570 persons were found to be earning 12*s.* 11*d.* per week on an average: namely, men's average 22*s.* 3*d.*; women and girls', 8*s.*; boys', 6*s.* 8*d.* Mr. Baines, in an article in the 'Statistical Journal' for 1859, estimated that the woollen manufacturers (without the worsted) use up 156 million lbs. of British and foreign wool, 45 million lbs. of shoddy and mungo, and cotton to the value of 200,000*l.*; that the value of these fibres is about 10,500,000*l.*; and that the wages, oil, soap, dyes, profit, interest, rent, and wear and tear, raise the total value to 20,290,000*l.* He estimates that 150,000 persons were employed in the woollen manufactures in 1858; Mr. M'Culloch estimates 275,000 persons employed in the *woollen and worsted* manufactures in the same year.

From 1725 to 1820 all the cloths made and fulled in the West Riding were measured and stamped by officers appointed for that purpose, and from the returns made, it appears that there were fulled, in the West Riding, the following number of pieces of broad and narrow cloth, in the years named:—

	Broad.	Narrow.		Broad.	Narrow.
In 1726	26,671	..	In 1786	158,792	123,025
1746	56,637	68,775	1806	290,269	175,334
1766	72,575	78,893	1816	325,449	120,901

The woollens and worsteds exported in 1820, 1830, and 1840, had a value of 5,587,758*l.*, 4,728,666*l.*, and 5,327,853*l.* respectively. In 1845, 1850, and 1855, the value rose to sums varying from nine to ten millions sterling annually. The figures for the year 1860, given somewhat more in detail, will show in what way the manufacture subdivides itself into kinds. The exports in the year just named were as follow:—

Woollen cloth of all kinds	579,135 pieces.
Mixed stuffs, flannels, blankets, and carpets	93,079,584 yards.
Mixed stuffs entered at value	£493,526
Worsted stockings	272,332 dozen pairs.
Worsted stuffs	2,616,756 pieces.
Woollen and worsted yarns	245,839 cwts.

The value of all these exports exceeded 16,000,000*l.* The United States were the largest purchasers of the woven goods; the yarn went in greater quantity to Germany.

WOORARI. *Wooraly, Œurari, Urari.* The extract of the bark of the *Strychnos toxifera*, which is used by the Indians of Guiana to poison their arrows. Recent investigation has shown that the poisonous principles of this extract are strychnine and brucine. [Nux Vomica, Alkaloids of.]

WORK, UNIT OF. The sum of the dynamical effect produced by a prime mover in a given time is known in books upon mechanism by the term of its *unit of work*; but in order to be able to compare the relative effective values of the various motors it is customary to refer them to the unit of work most generally considered to represent the normal conditions of an artificial prime mover. In such cases the amount of work is taken as being represented by a weight raised through a definite height in the time given; and as horse-power was formerly the one most commonly used for mechanical purposes, the custom has arisen of comparing the efficient power of machines in proportion to the units of work they can perform, each of which units is equal to the unit of work performed by a horse supposed to raise a weight vertically. Writers upon physics are far from being unanimous as to the real value to be assigned to the *horse-power*; but in England it is generally considered to be equivalent to a weight of 33,000 lbs. raised one foot high in a minute; or to 550 lbs. raised 1 foot in a second; and that unit of work is adopted as the term of comparison in the majority of cases when the powers of steam engines are compared. In the case of the pumping engines of the Cornish mines, the unit of work is made to refer to the weight of water actually raised by the combustion of a hundred weight of coals, and the unit of work is technically known in that district by the term, "duty."

Of course the amount of work performed by any prime mover must vary under the ever varying conditions of practice; and especially when men, horses, or other animals, are employed must the effort they can exert depend upon individual constitution, and upon accidental circumstances. The units of work assigned to the respective motors mentioned below must, therefore, only be considered to represent a rude kind of average in each instance, and particular attention must be paid to the fact that there is for all of them a velocity of the point of application of the power, an effort, and a duration of that effort, which are the most favourable for the useful effect. The average unit of work may often vary from ¼ to ⅓ above or below the quantities cited, according to the age, or the health, of the animal motors, or to the climate in which they work. The table is extracted from Poncelet's 'Mécanique Industrielle.'

The unit of work of steam engines, the horse-power, has long ceased to have any real meaning, for the real power, as ascertained by the dynamometer, is invariably in excess of the nominal horse-power of the engines. The common rule for calculating the *nominal* power of engines, whose pistons move at the velocities prescribed by Watt's rules, is however as follows: multiply the square of the diameter of the cylinder, in inches, by the velocity of the piston, in feet, and divide the product by 6000; the product will be the number of nominal horses' power. As this formula does not include any term expressing the expansive power of the steam, it must evidently be unsatisfactory; the real power may be ascertained by means of the indicator as follows. Multiply the area of the piston by the residual pressure, after deducting for the friction and the loss of power in working the air pump (this is usually 1¼ lbs.), and by the velocity of the piston in feet per minute; the product divided by 33,000 will represent the real *effective* horse-power applied to the main shaft. In both these cases, the unit of work of the horse-power is taken at 33,000 lbs. raised 1 foot high per minute. In Watt's time this amount of work could only be secured by the combustion of about 16 lbs. of coal per horse-power per hour; at the present day, in ordinary condensing engines, only from 7 to 8 lbs. are required; whilst in the best expansion-geared engines with surface condensation the same result is obtained by the combustion of 2 lbs. of coal.

Description of Work.	Weight raised.	Velocity per second.	Unit of work per second.	Length of working day.	Total work in a day.
	lbs.	feet.	lbs. × ft.	hours.	lbs. × ft.
A man mounting an easy staircase, or an incline, without a load, his work consisting simply in moving the weight of his own body	143	0·5	71·5	8	2,059,200
A man raising weights by means of a cord and pulley, which renders necessary the return of the cord without a load	39·6	0·66 say 0·67	26·53	6	573,048
A man raising weights by his hands	44	0·56	24·64	6	532,224
A man carrying a weight on his back up an easy incline, and returning without load	143	0·13	18·59	6	401,544
A man raising materials by a wheel-barrow, on an incline of 1 in 12, returning unloaded	132	0·065	8·58	10	308,880
A man throwing earth by a spade a height of 5 feet 4 inches	5·94	0·66 say 0·67	3·98	10	143,280
A man working a pin-wheel or a drum—					
1st, at the level of the axle	132	0·5	66	8	1,900,800
2nd, at bottom of wheel	26⅖	2·34	61·8	8	1,779,840
A man walking and pushing, or drawing horizontally, in a continuous manner	26·4	2	52·8	8	1,520,640
A workman acting upon a winch	17·6	2·5	44	8	1,267,200
A workman pushing and pulling alternately in a vertical direction	13·2	2·5	29	10	1,044,000
A horse harnessed to a carriage going at a walking pace	154	3	462	10	16,632,000
„ „ „ at a trot	96·8	7·22	699	4·5	11,323,800
A horse in a mill, at a walking pace	99·0	3	297	8	8,553,600
„ at a trot	66·0	6·56	433	4·5	7,014,600
An ox in a mill, at a walking pace	132	2	264	8	7,603,200
Mule „ „	66	3	198	8	5,702,400
Donkey „ „	30·8	2·67	82·24	8	2,368,512

WORKHOUSE. Relief to the indigent is of two kinds, in-door relief and out-door relief. In-door relief is relief in the workhouse. At first workhouses appear frequently to have combined the character of a bridewell. In the reign of Edward VI. the poor of London were classed into three great divisions, and the third comprised the "thriftless poor," namely, 1, the rioter that consumeth all; 2, the vagabond that will abide in no place; 3, the idle person, as the strumpet and others: and the king, who had been moved to the necessity of almsdeeds by a sermon of Bishop Ridley's, provided hospitals for "the poor by impotency" and "the poor by casualty," and Bridewell was allotted to the "thriftless poor." The workhouse at Hamburg, one of the oldest institutions of the kind in Europe, is still called the Correction and Poor House. The Canterbury Local Act, passed in 1727, expressly orders the bridewell and workhouse to be kept up within the same precincts; and they were only separated under an act passed in 1842. A century and a half ago it was common for writers to speak of the workhouse as a place where idlers and vagabonds were set to work. (See 'Workhouse,' Johnson's 'Dictionary.') The general character of our early statutes relating to the poor was harsh, and indigence was treated as a penal offence.

One of the great objects of the 43 Eliz., c. 2, the foundation of our present poor-laws, was to provide employment for the destitute. The overseers and justices of the peace were directed to set to work children whose parents were unable to maintain them; and also adult persons who had no means of maintaining themselves, and who used no ordinary and daily trade of life; for which purpose, with the fund raised for the relief of the poor, a convenient stock was to be purchased of flax, hemp, wool, thread, iron, and other ware and stuff. The 43 Eliz. also authorised overseers and churchwardens to build cottages on waste land for the poor to inhabit, and to place inmates, or more families than one, in one cottage or house, such cottages or houses to be used thereafter only for the poor. Workhouses in former times were generally called houses of industry, and for the most part a profit was expected to be derived from their labour, at any rate, to the extent of making such institutions in some measure self-supporting. The house in such cases became a linen or woollen factory; or sacks, nets, and a variety of other articles, were manufactured. Sometimes land was rented or purchased, and the inmates of the workhouse were employed in agricultural labour. The final extinction of poor-rates was regarded as a not impossible result of these schemes of workhouse industry. In 1704, when the popularity of these schemes was at its height, De Foe clearly pointed out their inevitable operation, and especially their effect on independent labour; but he was scarcely heeded. Nearly a century afterwards houses of industry were erected in Suffolk on a greater scale than had previously been attempted. Instead of being employed as a test of destitution, these houses were intended to provide occupation for all the unemployed.

Previous to the passing of the Poor-Law Amendment Act, in 1834, the poor-houses (or workhouses) presented, generally speaking, only accumulated instances of mal-administration. Absence of classification, discipline, and employment, and extravagant allowances, rendered them prolific nurseries of pauperism and vice. Some of the cases of workhouse corruption would be ludicrous, had they not exhibited practices so thoroughly demoralising. In by far the greater number of cases, the workhouse was a large almshouse, in which the young were trained in idleness, ignorance, and vice; the able-bodied maintained in sluggish and sensual indolence; the aged and more respectable exposed to all the misery that is incident to dwelling in such a society without government or classification; and the whole body of inmates subsisted on food far exceeding both in kind and in amount not merely the diet of the independent labourer, but that of the majority of the persons who contributed to their support. By 30 Geo. III., c. 49, passed in 1790, the right of visiting any workhouse at all times of the day was conferred on justices of the peace and clergymen; and on their representation the overseers were liable to be summoned at quarter-sessions, when the justices could make orders and regulations for the remedy of any defects in the workhouse management. The chief recommendation of the Commissioners of Poor-Law Inquiry in 1834 was to *unite* parishes for better workhouse management, and the relief of the destitute poor. This is the origin of the Poor-Law Unions. As soon as the Poor-Law Commissioners were appointed, they directed their attention to the uniting of parishes into unions for the purpose of the administration of relief by boards of guardians elected by the ratepayers, and to the general adoption of the workhouse system; but their main reliance for the discouragement of pauperism, and for the establishment of independent habits amongst the labouring classes, they said, was founded on the workhouse system. Out-door relief to the able-bodied poor is now prohibited in all those unions which have efficient workhouse accommodation,—with the following exceptions. 1. Where the destitute poor shall require relief on account of sudden and urgent necessity. 2. Where he or she shall require relief on account of any sickness, accident, or bodily or mental infirmity affecting him, or any of his or her family. 3. Where he or she shall require relief for the purpose of defraying the expenses, either wholly or in part, of the burial of any of his or her family. 4. Where the person, being a widow, shall be in the first six months of her widowhood. 5. Where the person shall be a widow, and have a legitimate child or children dependent upon her, and incapable of earning his, her, or their livelihood, and have no illegitimate child born after the commencement of her widowhood. 6. Where the person shall be confined in any jail or place of safe custody. 7. Where the person shall be the wife or child of any able-bodied man who shall be in the service of her majesty as a soldier, sailor or marine. 8. Where any able-bodied person not being a soldier, sailor or marine, shall not reside within the union, but the wife, child, or children of such person shall reside within the same, the Board of Guardians, according to their discretion, may, subject to certain conditions, afford relief in the workhouse to such wife, child or children, or may allow out-door relief for any such child or children being within the age of nurture, and resident with the mother within the union. These exceptions may, however, in special cases be further extended, with the sanction of the Poor-Law Board previously obtained. In all other cases the guardians may grant relief either in or out of the workhouse as they may deem expedient under the circumstances of each case.

Workhouses are governed under the rules and regulations which are contained in the consolidated order of the Poor-Law Board. Paupers are admitted to them in one or other of the following modes:—1. By a written or printed order of the Board of Guardians, signed by their clerk. 2. By a provisional written or printed order, signed by a relieving officer or an overseer. 3. By the master of the workhouse (or during his absence, or inability to act, by the matron), without any order, in any case of sudden or urgent necessity. The paupers are divided into the following classes:—1. Men; infirm through age or any other cause. 2. Able-bodied men, and youths above the age of fifteen years. 3. Boys above the age of seven years and under that of fifteen. 4. Women infirm through age or any other cause. 5. Able-bodied women, and girls above the age of fifteen years. 6. Girls above the age of seven years and under that of fifteen. 7. Children under seven years of age. The following officers are appointed for each workhouse, except in the case of very small workhouses, when some of the offices are combined—namely, a chaplain, medical officers, master, matron, schoolmaster, schoolmistress, porter, and nurse, with such assistants as may be deemed necessary. These officers are all appointed by the boards of guardians of the respective unions; and they are paid adequate salaries by the guardians, subject to the approval of the Poor-Law Board; and, with the exception of the two first, in addition to their salaries, are allowed board and lodging in the workhouse. Though the officers are appointed by the boards of guardians, unless they voluntarily resign they cannot be removed except by an order of the Poor-Law Board. For detailed information regarding the government of the workhouse, that is, the admission of paupers, their classification, discipline and diet, punishment for misbehaviour, and the duties of the workhouse officers, the 'Poor-law Board Orders,' edited by W. Cunningham Glen, Esq., Barrister-at-Law, should be consulted.

There are 623 unions and parishes under separate boards of guardians, and in which relief to the poor is administered under the provisions of local acts of parliament, all of which, with the exception of about ten unions, have workhouses capable of accommodating from a comparatively small number up to 3500 paupers (in the Liverpool workhouse), which is the largest number allowed in any one workhouse. There are 708 workhouses in England and Wales, and the maximum number of paupers to be admitted at any one time into each workhouse is in each case limited by the Poor-Law Board; the total accommodation afforded by all the workhouses provides for about 218,000 persons, besides accommodation for the officers of the establishments.

The following are the numbers of paupers of the respective classes who were maintained in the workhouses in England on the 1st July, 1860, and 1st January, 1861, respectively:—

		July 1, 1860.	Jan. 1, 1861.
Able-bodied	Males	3,260	7,589
	Females	9,848	15,813
	Children	12,142	19,441
Not able-bodied	Males	23,047	29,227
	Females	18,927	21,735
	Children	25,544	28,480
Lunatics, insane persons, and idiots.	Males	3,344	3,512
	Females	4,646	4,837
	Children	319	327
Vagrants		1,146	1,179
Total		102,223	132,140

Under ordinary circumstances, therefore, the workhouses are only about half full, and the excess of accommodation provided is reserved to meet any extraordinary pressure that may occur.

During the year ended the 25th March, 1860, the total expenditure out of the poor-rates in and connected with the relief of the destitute poor, amounted to the sum of 5,454,964*l.* 7*s.*, and of that sum 912,360*l.* 7*s.* was expended in the relief to the poor in workhouses; but to that sum must be added the cost of the workhouse establishments, including the salaries of the officers, to arrive at a correct estimate of the cost of workhouse relief. These items, however, are not separately distinguished from the cost of the union salaries generally; which during the year referred to amounted to the sum of 644,799*l.* 9*s.* Taking the whole of the workhouses, the average cost of maintaining each pauper therein averages about 3*s.* 2*d.* per week, which is the cost of food, clothing, and necessaries charged to the in-maintenance accounts; the cost of the food being about 2*s.* 11*d.* per week, and of the clothing and necessaries about 3*d.* per week for each pauper. In some workhouses, however, the cost is much higher, and in others considerably less than those amounts.

The cost of erecting the Liverpool workhouse, which is the largest, amounted to upwards of 120,000*l.* Some of the smaller workhouses cost as low as 1500*l.* building, but taking them altogether, the average cost of each may be stated at about 8000*l.*; so that, there being 708 workhouses, the total cost of these buildings may be taken as representing the sum of five millions and a half (exclusive of interest), which sum was raised by loans secured upon the poor-rates, repayable by annual instalments, including interest, in periods varying from ten to twenty years.

Further on the subject of the poor-law statistics the reader is referred to the paper on the 'English Poor-Rate,' by Mr. Frederick Purdy, in the 'Journal of the Statistical Society of London,' for September, 1860.

WORLD. [UNIVERSE.]

WORKS AND BUILDINGS, BOARD OF. [WOODS AND FORESTS.]

WORMS, HUMAN. The body of man, like that of the lower animals, serves as a locality for the residence of several of the lower forms of animals which are known by the general name of worms. These creatures all belong to the lower forms of the annulose group of animals, and are sometimes grouped together under the name of Entozoa [ENTOZOA, in NAT. HIST. DIV.]. This is not, however, a philosophical classification, as many animals belonging to this group in point of structure have not necessarily parasitical habits. Another reason for getting rid of the term Entozoa will be found in our present knowledge of the history of the development of some groups of these creatures, as there is reason to believe that they do not pass all their existence within the bodies of other animals. The most important observation made with regard to these animals in modern times, is the identity of those forms of worms called *cystic*, with those which have been called *cestoid*.

The researches of Siebold, Küchenmeister, Leuckart, and Rainey, have now placed this matter beyond a doubt. The history of the common tape-worm (*Tænia solium*) of the human body may be taken as a type of the whole. The eggs of this worm are contained in the segments of the mature worm, which are called *proglottides*. [ANTHELMINTICS.] These eggs, in order to their future growth and development, must be swallowed and submitted to a process of digestion by some other animal before they reach maturity. This process may occur in many species of animals, but that in which it takes place most commonly is the pig. In the intestines of the pig the egg becomes an embryo, which is supplied with six hooks, by means of which it penetrates the tissues of the intestines, and entering the blood-vessels is carried by the current of the blood to the various organs of the body. This embryo having reached a place of rest, is developed into the cystic worm known by the name of *Cysticercus cellulosæ*. This form of the worm is well known, and produces in the flesh of the pig that appearance which is called in the markets "measly pork." Here it remains and dies, unless the flesh containing it is eaten by some other animal. When eaten by man and submitted to the process of digestion, the cystic worm is further developed. In the cyst there is a head called the "Scolex head," supplied with suckers and hooks, adapted to laying hold of the mucous membrane of the intestines, which, when effected, results in the growth of those segments which are known as the characteristic of the tape-worm. The scolex head is now the head of the tape-worm, and the segments are the proglottides which continue to increase, and eventually each segment is developed into a sexual being, containing both the male and female organs of generation, and the eggs are produced. These facts have been well established by experiments, made by both Von Siebold and Küchenmeister. Man is also subject to the attack of cystic worms, *Echinococcus*, &c., which attain their mature development in other animals. The following is a classification of the worms at present known to inhabit the human body:—

Division ANNULOSA.
Subdivision ANNULOIDA.
Order SCOLECIDÆ.
Section PLATYELMIA—Flat worms.
  Family TÆNIADÆ = CESTOIDÆ.
    A. Mature States:—
      Bothriocephalus latus—Broad Tape-worm.
      Tænia solium—Common Tape-worm.
      Tænia mediocanellata.
      Tænia nana.
      Tænia? (Cape of Good Hope.)

LIST OF MATURE AND IMMATURE WORMS, AND THEIR HABITATS.

Immature State.	Habitat.	Mature State.	Habitat.
	TENIADÆ.		
Cysticercus cellulosæ	Pig	*Tænia solium*	Man.
C. fasciolaris	Rat, mouse	*T. crassicollis*	Cat.
C. pisiformis	Rabbit	*T. serrata vera*	Dog.
C. tenuicollis	Sheep, horse, monkey, man	*T. ex cysticerco tenuicolli*	Dog.
C. innominatus Hyperdæi	Mole, field-mouse	*T. tenuicollis*	Marten, weasel.
C. longicollis Hyperdæi	..	*T. crassiceps*	Dog.
Cœnurus cerebralis	Sheep, ox	*T. cœnurus*	Dog.
Echinococcus veterinorum (*E. scolicipariens*, Küch.)	Man, ruminantia	*T. echinococcus sc.*	Dog.
E. hominis (*E. altricipariens*, Küch.)	Man, domestic an.	*T. echinococcus alt.*	
	TREMATODA.		
Cercæria	Fresh water mussel	*Distoma hepaticum*	Sheep, man.

The tape-worms of the lower animals have the same origin with those of man, and their history has now been traced in a large number of animals. Thus, the dog is liable to the attacks of a tape-worm (*Tænia cœnurus*). The egg of the *T. cœnurus*, on being swallowed by the sheep, produces a cystic worm in its brain, which has long been known by the name of *Cœnurus cerebralis.* This worm produces the "staggers" in the sheep; and when dogs get access to the brains of sheep under these circumstances they produce the *Tænia cœnurus.* The cat is liable to a tape-worm called *Tænia crassicollis*, the cystic stage of which is found in the liver of the rat or mouse, and is known to naturalists under the name of *Cysticercus fasciolaris.* Even the Trematode worms pass through stages of this kind, and the *Cercœria* of the mussel becomes the *Distoma* of the sheep.

A question of some interest has been raised as to whether we ought to regard these parasites as necessarily connected with a diseased state of the body, and therefore to be got rid of at any cost. It is a curious fact with regard to tape-worms and neuratoid worms, that they will exist for years without producing any inconvenience. By the Abyssinians they are regarded as indicative of health, and a negro slave among them is valued higher for it. It is often observed that persons who must have been the subjects of tape and other worms for a long time past do not suffer till they become aware of the existence of these creatures. At the same time there can be no doubt that certain states of the health favour the excessive development both of the immature and mature states of the various species of worm, and that they then become sources of serious inconvenience. The symptoms attributed to the presence of tape-worms are very numerous. Küchenmeister, in his work on the 'Parasites of Man' (translated for the Sydenham Society by Dr. Lankester), gives the following account of symptoms observed in 100 cases in which tape-worms were known to exist:—68 suffered from cerebro-spinal affections and partial or general convulsions; 49 from nausea, sometimes with vomiting and fainting; 42 with pains in the abdomen; 33 from disordered digestion; 31 from irregular and voracious appetite; 19 from headache; 17 from colic; 16 from abdominal movements; 15 from dizziness; 11 from shifting pains. It will at once be seen that none of them can be pronounced as undoubted symptoms of worms, as they may all result from other kinds of disorder. The only distinguishing sign that can be relied on without doubt, is the discharge of the proglottides, or portions of the worm, from the bowels. These being witnessed, the case is certain.

The remedies recommended for cestoid and other worms are very numerous. When the general health is bad it should be improved. There are, however, certain remedies which act in an especial manner on the worm in the intestines which should always be administered. These are called anthelmintics. [Anthelmintics.] Most of these act in two ways:—1. They destroy the worm, and act as helminthicides. 2. They expel it when dead or enfeebled, and thus act as purgatives. The best of these is oil of turpentine. It has been used extensively in Great Britain; and Küchenmeister, whose authority is great on this subject, says—"It is certainly one of the most energetic remedies against tape-worm, and justly merits application in those cases in which pomegranate-bark has produced no result." It is a very disagreeable remedy, producing sometimes serious effects in the nervous system and sometimes strangury. Consequently medical men try other remedies first. Of these, koupo, male fern, pomegranate-bark, and camelea, are preferred. Koupo has undoubtedly proved of service, but Küchenmeister says he has always been more or less unlucky with this remedy. The male fern is also useful. The decoction of the root, the powdered sort, or etherial-oil, are given. Rapp says by far the most efficient form is the fresh root.

Küchenmeister gives the preference to pomegranate bark. He uses a thick extract of the bark, and says he "prefers it to all other remedies against tape-worm." It dislodges, he says, the head of the worm more effectually than any other remedy.

For a good abstract of the present state of knowledge with regard to tape-worms in man, see an Essay on this subject by Dr. D. F. Weinland, published at Cambridge, U.S., 1858.

WORSTED MANUFACTURE. [Woollen and Worsted Manufacture.]

WORT. [Brewing.]

WOUD. [Weld.]

WOULFE'S APPARATUS. Under various forms, and with several modifications, this apparatus is much employed in chemical operations. The arrangement, first described by its inventor in the 'Philosophical Transactions,' is inconvenient in form; we shall therefore give a description of one of several improvements to which it has been subjected. A retort *a* (*fig.* 1.) is attached and secured by means of lute to the first receiver *b*, which has a right-angled glass tube, open at both ends, fixed into its tubulure; and the other extremity of the tube is made to terminate beneath the surface of distilled water, contained, as high as the horizontal dotted line, in the three-necked bottle *c*. From another neck of this bottle a second pipe proceeds, which ends, like the first, under water contained in a second bottle *d*. To the central neck a straight tube, open at both ends, is fixed, so that its lower end may be a little beneath the surface of the liquid. Of these bottles any number may be employed that is thought necessary. The materials being introduced into the retort, the arrangement completed, and the joints secured in the manner to be presently described, the distillation is begun. The condensable vapour collects in a liquid form in the balloon *b*, while the evolved gas passes through the vent-tube, beneath the surface of the water in *c*, which continues to absorb it till saturated. When the water of the first bottle can absorb no more, the gas passes, uncondensed, through the second right-angled tube into the water of the second bottle, which, in its turn, becomes saturated. Any gas that may be produced, which is not absorbable by water, escapes through the vent-tube *e*, and may be collected, if requisite, in an air-jar filled with and inverted in water in the pneumatic trough. This is represented in *fig.* 2 by *f*, *f*, and *g*.

Fig. 1.

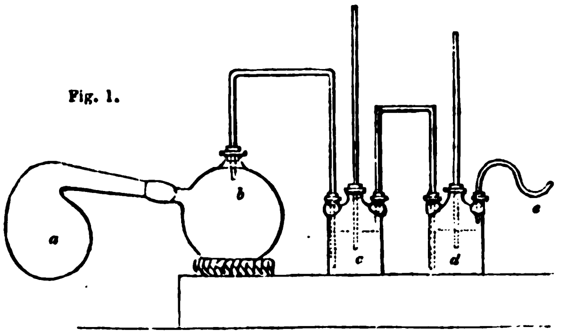
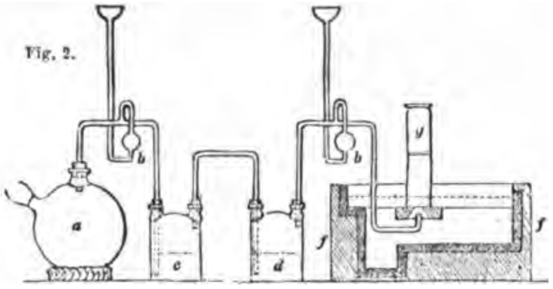


Fig. 2.



Supposing the bottles to be destitute of middle necks, and consequently without the perpendicular tubes, the process would be liable to be interrupted by an accident; for if, in consequence of diminished temperature, an absorption or condensation of gas should take place in the retort *a*, and of course in the balloon *b*, it must necessarily ensue that the water of the bottles *c* and *d* would be forced by the pressure of the atmosphere into the balloon, and possibly into the retort, which might cause a dangerous explosion; but, with the addition of the central tubes, a sufficient quantity of air rushes through them to supply any accidental vacuum. This inconvenience, however, is still more effectually obviated by Welther's tube of safety (*fig.* 2) *b*, which supersedes the expediency of three necked bottles. The apparatus being adjusted, a small quantity of water is poured into the funnel, so as to about half fill the ball *b*. When any absorption happens, the fluid rises in the ball till none remains in the tube, when a quantity of air immediately rushes in and supplies the partial vacuum in *a*. On the other hand, no gas can escape under ordinary circumstances; because any pressure from within is instantly followed by the formation of a high column of liquid in the perpendicular tube, which resists the egress of the gas.

We have already observed that various modifications of this apparatus have been proposed, an account of which may be seen in different chemical treatises: the above description is taken almost entirely from Dr. Henry's 'Elements.'

WOUNDING. [Maim.]

WOUNDS, in Surgery, are solutions of the continuity of the soft parts of the body effected by some external agent, and attended with a greater or less amount of bleeding. Wounds vary in their character according to the kind of instrument by which they have been produced, as well as the greater or less amount of force with which it has been applied. In order to facilitate the description of treatment, surgical writers have divided wounds into several kinds. Thus they are spoken of generally under the terms incised, punctured, contused, lacerated, poisoned, and gunshot wounds. Wounds of particular parts, requiring peculiar treatment, are also described, as of the head, throat, chest, &c.

Incised wounds, cuts, or *incisions* are produced by cutting instruments, and are free from contusion and laceration. *Punctured wounds*, or *stabs*, are caused by pointed weapons, as bayonets, lances, nails, thorns, &c., penetrating deep into the flesh. *Contused* and *lacerated wounds* are produced by the violent application of hard blunt and obtuse bodies to the soft parts; and under this head might be included *gunshot wounds*. *Poisoned wounds* are those which are complicated with the introduction of a poison into the wounded part. Wounds are more or less dangerous according to the extent of soft parts they involve, the parts they occur in, and the state of health of the individual wounded. In small wounds, unless poisoned, the system generally suffers little in consequence; but when a large amount of soft parts is injured, symptoms of fever come on from twenty to thirty hours after the receipt of the wound, which require attention on the part of the surgeon, as, according to the constitution and circumstances of the patient, the fever may vary greatly, and require opposite modes of treatment. The fever is called symptomatic, and in most cases is inflammatory.

Incised Wounds.—The effect of a cut on any part of the body is to produce a gaping space, from which blood in most cases issues, and pain is felt. The blood arises from the blood-vessels of the part having been cut through or wounded, and the pain is caused by a similar injury to the nerves. The amount of blood that issues from a wound, as well as the pain, will always depend upon the nature of the part which is injured. Some parts of the body are very copiously supplied with blood-vessels which have few nerves, and *vice versâ;* so that neither pain nor bleeding is constant according to the size of the wound. The immediate danger of incised wounds does not so much arise from the extent of parts divided as upon the kind and size of the blood-vessels which are injured. Thus extensive wounds may occur on the back and other parts of the body without producing sufficient hæmorrhage to endanger life, whilst a small puncture of the jugular vein or femoral artery might speedily occasion death. The integrity also of some parts of the nervous system is so essential to life, that the slightest wound will produce an immediate cessation of the functions of the body. Thus a small puncture of some parts of the brain, cerebellum, and spinal cord will cause immediate death. The remote consequences of wounds also vary in some measure with the kind of tissues and the organs wounded. Wounds situated near moving parts sometimes never heal. Wounds of tendinous and ligamentous structures do not heal so rapidly as those of muscular and other tissues; and thus it is that wounds of the joints are frequently healed with great difficulty.

The amount of gaping of a wound depends on the kind of tissues cut through. The skin is elastic; and thus, whenever it is cut through, the wound gapes by reason of its elasticity. Where there is much cellular tissue the wound does not gape so much, as this tissue is not elastic. Wounds of muscles differ: if the cut is in the direction of their fibres, then the wound gapes but little; but if it be across the fibres, then, owing to their contractile nature, the wound gapes very considerably. Wounds may be also made to gape or to close their edges, according to the state of flexion or extension of the muscles under the part in which they are situated.

The vessels injured in incised wounds are either *arteries* or *veins*, and each require attention from the surgeon, as the bleeding from them requires somewhat different treatment. When an artery is wounded, there is an immediate retraction of the ends of its middle and internal coats within the outer or investing coat, and also a contraction of all the coats so as to diminish the calibre of the artery. Blood flows from both ends of a divided artery, but always in greater quantity from the orifice nearest the heart. The blood from an artery can easily be distinguished by its bright red colour and by its coming out in jerks. When a cut artery is left to itself, the effusion of blood is great, but the flow becomes less and less profuse, and in passing over the roughened surface of the external sheath, from which the two inner coats have been separated by retraction, particles of the blood adhere to its loosened filaments. These particles keep increasing in number, till at last the whole space between the end of the external sheath and the ends of the two retracted coats is filled up, the blood having formed there a firm coagulated mass. When this process is completed, the bleeding from the artery stops. This mass of coagulated blood is called the *external coagulum*, but the same process is carried on within the retracted inner coats of the divided artery, and the coagulum is continued up to the point at which the artery gives off one of its branches. This coagulum terminates with a conical extremity in the middle of the tube of the artery, and is called the *internal coagulum.* The blood also which is effused outside the artery altogether coagulates, and to some extent may assist in the natural process of arresting the hæmorrhage. But these coagula of blood would not be sufficient alone to restrain the hæmorrhage; another process follows, which permanently effects this. This consists in the effusion of lymph from the parietes of the artery itself. This lymph fills up the entire extremity of the artery, and is first deposited between the external and internal coagula, but it goes on increasing till at last it occupies their position, the coagula are absorbed, and the lymph, becoming eventually organised by the development within its substance of blood-vessels, forms a part, as it were, of the artery itself, and connects it more or less with the surrounding parts.

When an artery is only partially divided or punctured, a somewhat different process takes place. Blood is effused between the artery and its sheath, both above and below the wounded part. In consequence of this the artery is distended, and a difference in the relative positions of the internal coats and the sheath takes place, and the blood coagulating is confined by the sheath over the wounded part of the internal coats. Lymph is effused as in the former case, and the cure is only effected by the obliteration of the artery.

When the veins are wounded, the blood which is poured out is of a dark colour, and comes not by jerks, but in a uniform stream. There is not so much danger from the bleeding of a vein as an artery, and it is much more easily stopped. When a vein is cut through, the opposite ends are closed by blood and the subsequent organisation of lymph, as in arteries. If only slightly punctured, and longitudinally, veins quickly heal, as is seen in the common operation of venesection. When veins are wounded obliquely or transversely, the wound is closed by a coagulum of blood, and the lips of the wound secrete lymph, which eventually becomes organised, and blocks up the whole vein. Eventually the coagulum thus formed is absorbed. This reparative process is much longer in taking place than that which occurs in arteries under the same circumstances.

Treatment.—In the treatment of incised wounds the objects in view are, first, to arrest the hæmorrhage; secondly, to remove all foreign bodies that may have been introduced into the wound; and, thirdly, to promote the union of the divided parts.

The arrest of bleeding is easily accomplished by bringing the edges of the wound together, in superficial wounds, and wounds where no large arterial or venous trunks have been injured; but where large vessels have been injured, other means will be found necessary. There is nothing perhaps which distinguishes modern surgery more than the power which it has attained of arresting hæmorrhage. The surgeon, through his knowledge of the circulation and the means of arresting mechanically the flow of blood, can venture upon cutting through all but the principal trunks of the arterial and venous system. When the bleeding from a wound is great, the first thing that can be done to arrest it is to *compress* the trunk of the artery which supplies the part. This may be done by means of the tourniquet [TOURNIQUET], or a bandage so constructed as to press down upon the artery. The circulation of the blood in the arterial trunk being arrested, the hæmorrhage from the wound will in a great measure cease. Compression however can seldom be used for a sufficient length of time to act as a curative agent in stopping the flow of blood. In the first place, although pressure by bandage may stop the supply of blood through the principal arterial trunk, it will not stop it through deeper-seated branches; and, by arresting the return of the blood by the veins, it may, under certain circumstances, tend to increase the bleeding. Even when circumstances are most favourable, the tourniquet and bandages are likely to get displaced, and thus to suffer the return of the bleeding.

The most important of the means of stopping bleeding from wounds is the *ligature*. This consists in seizing the wounded ends of the artery with a pair of forceps, or passing through it a tentaculum, and then tying up the artery in the same way that the mouth of a full sack is usually tied. For this operation all the skill that is required is anatomical knowledge. Care should be taken, whilst the necessary instruments are being prepared, that the bleeding is prevented by pressure on the trunk of the artery, or by placing the finger over the bleeding orifice itself. The forceps which are mostly used on this occasion are the common dissecting forceps, but Mr. Liston recommends a pair of forceps with hooks at their points, and which, after having grasped the artery, are kept together by means of a button or hook. "When no assistant is at hand, and in cases of emergency, the surgeon provided with this little instrument, can tie vessels without the least difficulty; and in operations, when many vessels spring, several of these forceps can be applied: there is, besides, this great advantage in their employment, that a clumsy assistant can scarcely include the point of the instrument with the vessel." (Liston.) The immediate effect of a tightly-drawn ligature is to arrest the flow of blood, to divide the middle and internal coats of the artery at the ligatured part (the external sheath remaining entire), and to narrow the canal for some extent above the ligature. The same process of cure goes on then as when the artery heals spontaneously.

Other means of arresting hæmorrhage are sometimes employed, such as the application of styptics [ASTRINGENTS], sponge, the actual cautery, caustics, &c. These, however, are seldom advisable in the case of incised wounds. There is, however, a popular prejudice in favour of applying various styptics to cuts for the purpose of stopping the bleeding, and it cannot be too generally known that all these applications are injurious, and tend to retard the cure; and that in some instances loss of life is the consequence of these applications to wounds that would have got well had they been left to themselves. [HÆMORRHAGE; ARTERY; HEART.]

The second indication in the treatment of incised wounds is the removal of foreign bodies. Unless all extraneous substances are removed from a wound, its union will not be effected, and suppuration, abscesses, and perhaps sloughing, will occur. It is in gunshot wounds that this indication requires the greatest attention, but foreign bodies are occasionally introduced into incised wounds. [GUNSHOT WOUNDS.] Wounds from broken china, glass, and earthenware frequently have fragments of these substances in them. Sharp instruments are frequently covered with dirt and various impurities; hence the importance of cleaning even incised wounds. John Hunter advocated the leaving blood on the edges of the wound, as he supposed it was the blood that became organised and united the wound; but this is now found to be erroneous, and all surgeons advocate the practice of removing as much of the blood as possible from the wound.

The third indication in the treatment of incised wounds is to bring the edges of the wound together, and to retain them so in such a manner as shall favour their speedy union. Wounds may unite in two ways—either by the establishment of an inflammation, the result of which is the secretion of pus, and the formation of what are called *granulations*, or the throwing out from the wounded parts coagulable lymph, which, becoming organised, unites the edges of the wound together. This latter process is called *union by the first intention*, and should be the great object of the surgeon in treating wounds. Evident as it may appear, that to heal a wound as quickly as possible should be the great object of the surgeon, this universal rule amongst English surgeons is objected to by some continental writers of the present day. It was at one time supposed necessary that wounds should heal only after a long and tedious process of cure by granulation, and lint and tow, bandages, compresses, and a variety of other appliances were made use of to prevent nature from effecting the object in her own way. The remnants of this practice are still found amongst the populace in our own country and some surgeons on the continent. Amongst the latter, M. Roux, of Paris, has distinguished himself by advocating the cure of wounds made in surgical operations by bringing on the tedious process of granulation.

When the blood has ceased to ooze from the sides of a wound, an effusion of lymph takes place of a plastic character. Into this lymph vessels are projected by the process of growth from the sides of the wound, and an organised union of the whole wound will frequently take place in the course of forty-eight hours. Even the extent of surface laid open by amputation of the thigh is often securely united throughout its whole extent in the space of seventy-two hours. So readily does this process occur, that there are many instances on record of parts of the body having been totally severed, and yet union by the first intention has taken place. Garengeot, in his 'Traité des Operations,' mentions a case in which a soldier's nose was bit off by one of his companions, and, being restored to its natural position immediately, a permanent union of the separated part was effected. Fioraventi, Blegny, Balfour, Bossu, and others, have also recorded instances of the restoration of entire union of parts after total separation by accident. Hunter transferred the spurs of a cock to its comb, and the testicles of a cock into the abdomen of a hen, and found in each case that vascular union took place, and the vitality of the transferred part maintained. These instances only illustrated the restorative nature of the process of union by the first intention. It is not often that parts unite after having been once separated. A small vascular connection being preserved, tends greatly to render this process more likely to occur; and numerous instances are recorded of fingers and toes being nearly separated, and afterwards uniting by the first intention. One of the most remarkable examples in which the surgeon avails himself of a knowledge of this fact, is in what is called the Taliacotian operation. In this operation a new nose is made by paring the edges of the destitute part, and cutting a pyramidal piece of skin from the forehead, its union with the rest of the skin still being maintained at the point, and bringing it down upon the face in the form of a nose, when it unites with the pared edges, and a decent substitute for the lost member is thus produced. [TALIACOTIUS, GASPAR, in BIOG. DIV.]

In order to induce wounds to unite by the first intention, the edges ought not to be brought together till all bleeding has ceased, for the slightest quantity of blood retards and may altogether interrupt this process. When the edges of the wound are ready to be brought together, there are several modes which may be pursued of keeping them in contact. Previous to bringing the edges together, cold water may be applied to the wound upon lint. This will keep down any tendency to over-action or inflammation. It was at one time supposed that the process by which coagulable lymph was thrown out from wounds was one of inflammation, and that it was desirable that the part should be kept warm to encourage this sanatory inflammatory process. But the researches of the late Dr. McCartney, of Dublin, seem to have set this question at rest; and most physiologists look upon this process as a secretion going on under increased action, but not as an act of inflammation.

Of the various modes of keeping the edges of wounds in apposition, the application of adhesive plaster is the most common, and certainly applicable to the greater number of ordinary incised wounds. The plaster should be applied in such a manner as to maintain the edges of the wound in contact. There are, however, some wounds which are too extensive for the use of adhesive plaster, and then the suture is used, which consists in bringing the edges of the wound together by sewing them up. [SUTURE.]

On this subject Mr. Liston remarks, in his 'Elements of Surgery' (p. 208): "Of late I have greatly dispensed with stitches and the common adhesive plaster, using, instead of the latter, slips of glazed ribbon smeared with a saturated solution of isinglass in brandy, which is much less irritating and more tenacious than the common adhesive compost. The parts are fixed temporarily with a single stitch, or two at most, and cloths dipped in cold water are placed over the wound. The ribbons are not applied till the adhesive substance has partly congealed and the oozing of blood ceased. The divided margins being approximated by the fingers of an assistant, the ribbons are laid gently over and held for a few seconds. Soon after a sufficient number have been applied the stitches are withdrawn, being no longer necessary. No other dressing is required, unless suppuration occur; the ribbons will adhere firmly till the completion of the cure, and thus the pain and irritation caused by frequent dressing is avoided. Even the largest wounds, as after amputation, are treated in this manner with the most satisfactory results. Of late years a plaster, made by coating oiled silk with a solution of isinglass, has been used instead; the glazed surface of the slips is moistened and applied as here directed." Surgery is deeply indebted to Mr. Liston for the bold and fearless manner in which he has carried out a simple and natural treatment of incised wounds.

Wounds, however, under the best of treatment will not always unite by the first intention: the consequence is, that the parts which do not unite at once will suppurate, and granulations will be formed. This is called *union by the second intention*. [INFLAMMATION.] When this process takes place, then all applications to procure union by the first intention must be abandoned, and all attention must be given to curing the wound by the process of granulation. Plasters, sutures, and bandages must be removed; and where the inflammation is great, every means should be taken to arrest it. Suppuration should be encouraged by warm fomentations, by poultices, and above all by the warm-water dressing, which consists of nothing more than pledgets of lint dipped in warm water, and then covered over with oiled silk to prevent evaporation and cooling. When the inflammatory action is subdued and granulations are forming, gentle pressure should be employed for the purpose of avoiding the formation of more new matter by granulation than is absolutely necessary. The dressings at this period should be light. Some surgeons are fond of ointments, which may always be dispensed with; but in some cases of languid granulation a stimulating ointment is useful. Lotions are generally better. A weak solution of sulphate of zinc or nitrate of silver may be mostly employed with advantage. The wound itself does not require the washing and sponging and dabbing to which it is so frequently submitted; but the skin about the wound cannot be kept too clean and free from impurities of every kind.

Punctured Wounds.—These wounds are dangerous from their depth, and the internal effusion of serum and blood which usually attend them. In consequence of this, these wounds are frequently followed by severe inflammation and suppuration. These results used to be attempted to be obviated by the practice of dilatation. This, however, is severe practice, and only justifiable in cases of the existence of a foreign body. Setons are recommended by the French surgeons for these wounds, but there are so many objections to them, that they are seldom used by surgeons in this country. Whether these wounds unite by the first or second intention, they require to be healed upon the same general principles as incised and gunshot wounds.

Contused and Lacerated Wounds.—These result from the collision of blunt, obtuse, hard bodies, being forcibly driven against the living textures. Although these wounds may occur independent of gunshot, it is in the class of wounds called gunshot that the best examples of lacerated and contused wounds occur. The rapid introduction of powerful machinery into the manufactures of this country renders contused and lacerated wounds of very frequent occurrence in our large towns. In these wounds there is seldom much bleeding, arising from the coats of the arteries becoming twisted and doubled up by the force of their retraction. They are much more liable to have foreign bodies in them than incised wounds. Such wounds seldom unite by the first intention, but in their treatment this object should always be kept in view, as frequently portions of the wound may be induced to unite. During suppuration and granulation, the same plan of treatment should be pursued as when these processes occur in incised wounds. The constitutional symptoms arising from these wounds are generally more severe than from any others, and require attention. Symptomatic fever must be treated according to the same general principles laid down for the treatment of fevers. [FEVERS.] Another consequence of these wounds is that dreadful state of the nervous system called tetanus [TETANUS], which often resists all kinds of treatment.

Poisoned Wounds.—The principal forms of this class of wounds seen in this country arise from the bites of rabid animals, pricks and cuts received in dissection, and the bites of vipers and the stings of insects. The bites of rabid animals are unfortunately too common, and often in this country require the attention of the surgeon. When the poison is introduced into the system, it produces the fearful disease known by the name of hydrophobia, for which medical science has not hitherto found a remedy. [HYDROPHOBIA.] Where persons have been bitten by cats, dogs, or wolves in a rabid state, the wound should be immediately excised, and the nitrate of silver (lunar caustic) applied to the wound.

Dissecting Wounds.—Under this head may be included not only the punctures and cuts to which medical men are exposed in the examination of the dead human body, but all those wounds after which ill consequences ensue, in which there is reason to suppose some poison generated in an animal organisation has been introduced into the system. It is still sometimes discussed in books on surgery, as to whether the effects following these wounds are produced by a peculiar poison or are only the result of a slight wound in a constitution predisposed to disease. The frequency of the ill effects of these wounds amongst medical men, as compared with other classes of persons, equally liable to pricking and cutting their fingers, must decide this question in favour of the existence of a poison. It is not, however, as is generally supposed, that putrescent bodies and those advanced in decomposition are most injurious, for it is generally found that the worst consequences follow wounds from recent bodies, especially of persons who die of puerperal peritonitis. The consequences following these cuts are uneasiness and festering the wounded part, the absorbent glands up the arm become inflamed, there is pain felt in the arm and in the glands of the axilla: these symptoms are attended with more or less fever, and generally great anxiety. These symptoms sometimes increase, the cellular tissue of the arm and side becomes inflamed, abscesses form, and the patient sometimes dies from the fever or subsequent exhaustion. This disease is principally confined to medical men, and much difference of opinion has existed as to its treatment. Formerly tonics, wine, and brandy were administered, and active means taken to destroy the poison by caustic potash, liquor ammoniæ, nitric acid, &c.; but at the present day there is a general opinion in favour of mild antiphlogistic treatment, and having recourse only to tonics and wine when the symptoms seem to require it. Leeches, bleeding, purgatives, antimonials, and opium constitute the chief features of the treatment in the early and inflammatory stage. The application of lunar caustic, a solution of alum, and other things, have been recommended immediately after the receipt of the wound; but, after some considerable experience, it may be doubted if these things prevent the absorption of the poison. At any rate, if any good is to be done, the application must be immediate.

Bites of Venomous Snakes.—These are frequently fatal in tropical climates. The only snake that is to be feared in Great Britain is the viper. Its bite, however, is seldom fatal except where some peculiar state of the constitution is favourable. Immediately on the receipt of the bite a pain and a burning sensation are felt in the part, which are followed by rapid swelling and a livid discoloration of the part. The constitution becomes affected also rapidly, and there is giddiness, extreme prostration of strength, depression of spirits, faintness, syncope, a small quick irregular pulse, difficulty of respiration, profuse cold clammy sweats, confusion of vision, headache, vomiting of bilious matter, a general yellow tinge of the skin, and a great pain about the navel. These symptoms are observed in greater or less degree to follow the bites of most venomous snakes. The bite of some of the snakes of Africa and America is certainly fatal, and persons die in a few hours after receiving the wound.

In the treatment of cases of bites from snakes, the first object should be to endeavour to prevent the passage of the poison into the system. Various modes are adopted for fulfilling this intention. The most effective is the immediate excision of the part. This will hardly be required after the bite of the British viper, as it seldom proves fatal; but it is frequently the only remedy with regard to tropical snakes. The application of the tourniquet or a ligature above the wounded part has been recommended; also the application of cupping-glasses. These remedies, however, do not extract the poison, and only arrest its effect. The application of caustic may in some instances have the effect of destroying the poison. Various local applications have had a great reputation for their prevention of the effects of the poison of snakes, but none of them seem entitled to any consideration. The treatment of the constitutional symptoms consists in the administration of stimulants: of these, ammonia is preferred. It is the basis of the *Eau de luce*, a remedy once very popular for the bite of snakes. Mr. Ireland, whilst in the West Indies as a surgeon to a regiment, employed arsenic in doses of one grain as a remedy against the effects of the bite of the *Coluber carinatus*. In South America, the plant they call Guaco is said to have a very beneficial effect. Poeppig, in his 'Reise,' has collected all the evidence which he could procure of the value of Guaco in these cases, but this is far from being satisfactory as to the value of this remedy. Cases from the bites of rattlesnakes and other poisonous serpents have occurred in this country, as these reptiles are often brought over here for the purposes of exhibition. A man died a few years since from this cause in St. George's Hospital.

Wounds of Particular Parts of the Body.—When any of the viscera of the body are wounded, questions frequently arise as to the treatment, which can hardly be answered by general principles: hence the wounds of particular parts of the body require consideration. Wounds of the head are frequently accompanied with concussion and compression requiring a modification of the treatment. Wounds of the scalp are also frequently attended with severe inflammatory symptoms, and no injuries of the body require more attention and close watching than these. Of all wounds which the surgeon is called on to treat, those of the throat are perhaps the most common, and require the most prompt attention. These wounds are generally the result of attempted suicide, and vary in extent according to the greater or less determination of the individual, as well as the edge of the instrument used for effecting the wound. The first thing to be attended to in these cases is to arrest the hæmorrhage, which must be done by placing ligatures on the wounded arteries.

When the trachea is opened, the entrance of blood into the lungs should be avoided as much as possible, as its existence there as a foreign body may bring on inflammation of the lungs. When a wound occurs in the larynx above the rima glottidis, every attention should be paid to removing anything that may irritate the glottis or prevent the free passage of air to the lungs. When the œsophagus is wounded, all the food of the patient should be administered by means of a tube passed through the mouth, nostrils, or the wound. It is sometimes the case that a surgeon sent for to a cut throat will attempt immediately to bring the edges of the wound together by sutures. If this be done the chances are that the patient will die of suffocation as soon as this is effected. When the bleeding has ceased, an attempt should be made gradually to bring together again the disunited parts. This is frequently done with the most perfect success, and sometimes the very worst cases of cut throat will recover. It will, however, generally require great skill and attention on the part of the surgeon to meet all the difficulties that will arise in the treatment of cases where so many important organs are involved.

Wounds of the chest become dangerous when they involve the viscera of the thorax, and several important questions arise out of the nature and extent of these wounds. The most important complications of these are—1, the entrance of foreign bodies into the cavity of the thorax; 2, the injury of one or more of the intercostal arteries; 3, the protrusion of a portion of lung from the wound; 4, the occurrence of emphysema from the wounding the lungs; and 5, extravasation of blood in the cavity of the thorax. Wounds of the *abdomen*, when superficial, require the same treatment as wounds generally. In penetrating wounds of the abdomen there is always great danger of the occurrence of peritonitis, which requires watching on the part of the surgeon. In cases where there is protrusion, the same general treatment will be required as for hernia. [HERNIA.]

(Cooper's *Dictionary of Surgery;* Cooper's *First Lines of Surgery;* Cooper's, Sir Astley, *Lectures on Surgery;* Liston's *Elements of Surgery.*)

WRANGLER. In old times the word Wrangle was used in the universities in the sense of "to dispute publicly," that is, to defend or oppose a thesis. The verb has gradually acquired a meaning of reproach (being made to imply uncivil and indecorous opposition), which it had as early as the time of Shakspere. In the 'Taming of the Shrew,' the teacher of music says to the scholar—

> "*Wrangling* pedant, this is
> The patroness of heavenly *harmony*."

The substantive *Wrangler* is hardly ever used, except as significative of a person who has passed the mathematical examination for the Bachelor's degree in the university of Cambridge (the word is unknown in Oxford) with such credit as to have had his name inscribed in the highest list, or list of wranglers. Of these the first in merit is the *Senior* Wrangler: but persons not accustomed to the phraseology of the University are apt to confound Wrangler with Senior Wrangler, that is, to imagine that any one of their friends who may have obtained a wranglership must necessarily be the first man of his year. The second list is that of *Senior Optimés*, as they are called, and the last that of *Junior Optimés*. All who are in these three lists (which are collectively called the mathematical Tripos) are said to take the Bachelor's degree *with honours*, or to *go out in honours;* those whose names appear in the Classical Tripos are said to take classical honours; while the remainder, who are called the *οἱ πολλοί*, abbreviated into "the Pol," though they equally take the Bachelor's degree, are not supposed to be *honoured*. But in point of fact, the last of the Junior Optimés, or the last on the list of honours, has always been considered an unfortunate person, and the name of *the wooden spoon* * has long been attached to his place. It is not as if all were examined together, and the honoured were selected out of the whole list: those who wish to go out in honours declare their intention and are examined separately; so that it frequently happens that the last of the honoured graduates is a person of very inferior attainments to many at the head of the unhonoured multitude. With regard to the facetious terms current in the universities, it should be known that the nicknames invented by undergraduates are generally adopted in the university, which become therefore real and well-known denominations. From the vice-chancellor to the freshman of yesterday, the last of the honoured is the wooden spoon: and he must be a formal man (a "regular Don" the undergraduates would call him) who, in speaking of the "previous examination," as it is styled in the grace of the Senate which established it, should use those words instead of "the little go," a term which was borrowed from the Oxonians as soon as the grace was passed.

There is no history extant of the original introduction of the terms wrangler, senior optimé, and junior optimé. Huber, whose history of our universities has been translated by Mr. Newman, says that every attempt he has made to unravel the skein of university technicalities has made him giddy with headache. A Cambridge man however finds no difficulty in seeing how the word was used, as applied to the manner in which an examination (not a public disputation) is passed. The examination which takes place in January, and at which a young man is said to "take his degree" (because in fact he then does all that will be asked of him, the old disputations having long been abandoned), in old times was not an examination for the B.A. degree, but for the right of being admitted to perform the disputations necessary for a degree. All degrees were originally gained by disputations, the substitution of an examination, to see whether the candidates were fit to dispute, being a thing of comparatively modern times. The vice-chancellor, when the examination was over, admitted the candidates, not to the Bachelor's degree, but "ad respondendum questioni," and the person thus admitted was called a questionist. The form of asking some trifling question, or keeping a mock act [Act] was afterwards performed between the questionist and the *Father* of his college, which is the name given to one of the fellows whose duty it is to present the candidates of his college to the vice-chancellor. On the Thursday after Midlent Sunday the vice-chancellor used to declare all the questionists (who in the interval had borne the name and assumed the dress of Bachelor of Arts) "actualiter esse in artibus baccalaureos." The term wrangler then must imply one who is held more than usually qualified to proceed to the disputations which were once the practical test of his fitness for the degree.

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* Since the institution of the classical honours, to which mathematical ones are a necessary preliminary at Cambridge, the wooden spoon has frequently been a distinguished classic, who did not need nor wish for anything except the formal place on the mathematical list, which was required previously to competition for a place in the classical one, though by recent changes classical honours may be obtained without the necessity of passing the mathematical examination, and the degree of B.A. be obtained through the classical tripos.

The Tripos lists are given in the 'Cambridge Calendar' from 1747 downwards; but the wranglers and senior optimés form one list till 1752 inclusive. It is said that the regular order of previous years cannot be ascertained, as the proctors were in the habit of making honorary senior optimés, and placing them in the list at pleasure.

WRECK. [Shipwreck.]

WRIT, a law term, which in its proper signification means a *writing* under the king's seal, whereby he confers some right or privilege, or commands some act to be done. Writs are either *patent* (open, commonly called *letters patent*, *literæ patentes*), which are not sealed up, but have the great seal attached to them; or *close* (*literæ clausæ*), which are, or are supposed to be, sealed up. The former are addressed to all persons indiscriminately, generally in these terms—"To all to whom these presents shall come;" the latter are directed to some officer or other individual. Of the former kind is the creation of a peer by patent, which is a royal grant of peerage; of the latter, the creation of a peer by writ, which is a summons to attend the house of peers by the style and title of some barony.

Writ in its ordinary and more limited sense is a term applicable to a process in *civil* or *criminal* proceedings. Civil writs are divisible into *original* and *judicial*; original writs issue out of the Court of Chancery, and give authority to the courts, in which they are returnable, to proceed with the cause; judicial writs are awarded by the court in which the action is already pending. These are again subdivided into *mesne* and *final*. Original writs (which have been superseded by the writ of summons) used to contain a *brief* statement of the plaintiff's alleged cause of action; and such a writ was called in law Latin *breve*, in law French *brief*: and this term was afterwards applied to judicial and other writs. Original writs issuing from Chancery were always witnessed, or *tested*, in the name of the king; judicial writs issued from that one of the superior common law courts in which the original writ was made returnable, and were tested in the name of the chief judge of such court.

There are many kinds of writs, some of the more important of which may be here mentioned. There is the writ to the sheriff of a county to elect a member or members of the Commons' House of Parliament, in case of a vacancy or general election, which issues upon the warrant of the lord chancellor, or in certain cases of the speaker of the House of Commons. The writ of *habeas corpus* (*ad subjiciendum*), which is directed to any person who detains another, commanding him to produce the body of the prisoner at such a time and place, together with the cause of his caption and detention, to do, submit to, and receive (*ad faciendum, subjiciendum, et recipiendum*) whatever the court or judge by whom the writ is awarded shall think fit. [Habeas Corpus.] There are various other writs of *habeas corpus*, for the purpose of bringing up prisoners to be charged in execution, to give testimony, &c.—the writs of *subpœna ad testificandum*, by which a party is commanded to appear at the trial of a cause, to give evidence under a pecuniary *penalty*; and of *subpœna duces tecum*, by which the party is commanded to bring certain specified documents for the purpose of the trial. A defendant privileged from the particular suit, or from being sued except before some other tribunal, is entitled to a writ of *privilege*, by which the court is required to discontinue the suit. In modern times a party is allowed his privilege without suing out any *writ* of privilege.

WRIT OF ERROR. Writs of error in purely civil suits are abolished by the Common Law Procedure Acts, and a more simple procedure for reviewing and correcting the decisions of the superior and other courts of record was established. [Error.]

In criminal cases there is a writ of error from all inferior courts to the Queen's Bench, and from that to the House of Lords.

WRIT OF INQUIRY. In cases where a plaintiff seeks to recover a specific chattel (as in the action of *detinue*), or a specific sum of money (as in *debt*), if the defendant allows judgment to go against him by default, this is considered as an admission that the plaintiff is entitled to what he claims; and the judgment therefore is final in the first instance, provided the plaintiff is content to take a small nominal sum for the damages resulting from the detention of the chattel or the debt. But where a plaintiff only seeks to obtain damages for an injury done to his person or his real or personal estate, or for the non-performance of a promise, if the defendant lets judgment go by default, this, though an admission that the plaintiff has a cause of action, does not operate as an admission of the amount of damages to which he is entitled; and such judgment is called interlocutory. In such cases, and also where the plaintiff seeks to recover substantial damages for the detention of a chattel, or of a debt, the intervention of a jury is required in order to ascertain for what damages the plaintiff is entitled to have final judgment. For this purpose, a *judicial* process, called a *writ of inquiry*, issues to the sheriff, commanding him to summon a jury to inquire what damages the plaintiff has sustained. If the plaintiff offer no evidence before the jury, a verdict must be found for nominal damages, as existence of *some* damage is admitted.

When the *inquisition* (or finding of the jury) is returned, the plaintiff is entitled to judgment for that amount.

WRIT OF SUMMONS. [Writ.]

WRIT OF TRIAL. All trials of causes in the superior courts took place formerly either at *bar* before the whole court, or at *nisi prius* before one of the judges of the court, or a judge or serjeant named in the commission of assize; but now, by the 3 & 4 Will. IV., c. 42, s. 17, in any action depending in any of the superior courts for any *debt* or *demand* in which the sum sought to be recovered and indorsed on the writ of summons shall not exceed 20*l.*, the court, or a judge (if satisfied that the trial will not involve any difficult question of fact or law), may order the trial to take place before the sheriff of the county where the action is brought, or some judge of an inferior court, and for that purpose a writ shall issue (called the Writ of Trial) directed to the sheriff or such judge, commanding him to try the cause before a jury, and to return such writ with the finding of the jury thereon indorsed. The statute applies only to actions for a *debt* or *demand* indorsed on the writ of summons; it does not therefore extend to cases where the action is brought for a wrong, or where the demand, being for unliquidated damages, the amount claimed cannot properly be indorsed on the writ of summons. The proceedings under the writ of trial, when directed to the sheriff, usually take place before his under-sheriff or other his deputy; and they are conducted in the same manner as at a trial at *nisi prius*: and the court will grant a new trial for the same causes as if the trial had been before one of the superior judges; but a new trial will not be granted upon the ground that the verdict is against the evidence, where the amount of such verdict is less than 5*l.*, unless such verdict be manifestly *perverse*.

WRITER, in Scotland, is a term of nearly the same meaning as attorney in England, and is generally applied to all legal practitioners who do not belong to the bar. The body who in Edinburgh enjoy, concurrently with writers to the signet, the privilege of conducting cases before the Court of Session, the Court of Justiciary, &c., are called solicitors of supreme courts (abbreviated S. S. C.), and the practitioners before the sheriff court of Aberdeen are by local custom called advocates. In each county there is generally a society of writers privileged to practise in the sheriff court and in the other local judicatories, who frame their own bye-laws, and regulate the terms of admission to their body. Individually, they are responsible for their conduct to the local judges before whom they practise: and as bodies they are, on the one hand, protected from the infringement of their privileges by unlicensed persons, and on the other, liable to judicial control if they attempt unduly to restrict the means of admission to their privileges.

WRITER TO THE SIGNET, abbreviated W.S., is the designation of the members of that class of attorneys or procurators who enjoy, in common with the solicitors of supreme courts, and with one or two smaller bodies, the privilege of conducting cases before the Court of Session, the Court of Justiciary, and the Commission of Teinds. Their peculiar privilege, however, is that of preparing the writs which pass the royal signet. The signet was a seal or die under the control of the secretary of state, with which the writs by which the king directed parties to appear in court, or ordered them to obey the decrees given against them, and other executive instructions, were stamped for the sake of authentication. In the 16th century, the persons who were entitled to present the writs which received the impression of the signet are supposed to have been the clerks in the secretary of state's office; and it is not known how or precisely at what time the persons who transacted this department of official business became converted into a body of private practitioners. Since the Union of 1707, the signet has been under the disposal of the Court of Session; but down to about the middle of last century the keeper of the signet was deputed by the secretary of state for the home department. Since that time he has been appointed under the great seal, and he names a deputy, who is a member of the society of writers to the signet, and by usage presides at their meetings. In the general case the summons by which an ordinary action is brought into the Court of Session requires to be signeted, and to be, as a preliminary, signed by a writer to the signet; although a member of one of the other privileged bodies may conduct the case. Advocation [Advocation], and some other analogous classes of procedure, required formerly to have the interposition of the signet; but this step in the procedure has been abolished. The writers to the signet now possess few privileges which are not shared by the other practitioners before the supreme courts. They still retain their privileges as to summonses, and they have the exclusive right of presenting signatures in exchequer, or of presenting, through the judges acting in exchequer, the indorsed drafts of the writs passing under the great and other seals in Scotland appended to crown charters, appointments to offices, &c. They have thus a monopoly of the business of making up the titles of the crown vassals in Scotland. The society require of their intrants an apprenticeship of five years, with a curriculum of university study, which includes two sessions of attendance, the one at Latin and the other at some other literary class, and four courses of attendance at law classes. The writers to the signet possess a library, the collecting of which commenced in 1755, by the purchase of some law books, to which works on other subjects were added in 1778. It is now supported by an annual grant by the society.

WRITING. [ALPHABET.]

X

X to an Englishman is the representative of what might as well be denoted by the two consonants *k s*. But in the Greek alphabet it was merely a guttural aspirate, equivalent probably to the German *c h*. The cause of this change in the power of the symbol appears to admit of the following explanation :—Before the employment by the Greeks of their character Ξ or ξ, it was their common custom to represent this sound by Χ Σ, as may be seen in Boeckh's inscriptions, rather than by Κ Σ, of which there exist however a few examples, as in the so-called Vanian Inscription. [ALPHABET, plates ii. and iii.] Now the Romans copied this Greek practice, and we consequently find in Latin inscriptions such forms as MAXSVMVS, PROXSVMVS, &c. See the Index of Marini's 'Fratelli Arvali.' So again coins give us the proper name AXSIVS, where the later orthography would have been AXIVS; and even existing manuscripts still bear traces of this orthography. Thus the Medicean MS. of Virgil has EXSESA ('Aen.', viii. 418), EXSVIT ('Aen.', viii. 567). But the Romans, being generally averse to the aspirated letters (*h* itself, though written, seems not to have been pronounced by them), had little or no occasion for the character X except in this combination with an S. The very sight therefore of an X, even before the eye came to the S, raised in the mind the idea of a sibilant, and thus rendered the sibilant itself a superfluous letter; which, because it was superfluous, would before long be omitted, and thus the single letter X would perform the office of the two consonants X S. It may be objected to this view, that in one of the oldest inscriptions, the Bacchanalian (see the plate in the seventh volume of Drakenborch's Livy), we have the form EXDEICERENT, where the letter in question already has the power of our modern *x*. This perhaps is an erroneous idea. It would probably be more correct to look upon the character in this word as the simple guttural, thus: *echdeicerent*, from which the later form *edicerent* would easily flow. A sibilant in this word would have given the same offence to a Roman, as εξδιδοναι would have done to a Greek ear. It should be recollected too that the old Latin preposition had the form *e c*, as seen in *ecfari*, *ecferre*, &c. (for thus did Cicero write these words), and that a sibilant was added only before the sounds *p*, *k*, *t*, or before a vowel. An argument against the view we have taken in reference to the change of power in the symbol might be founded upon the fact that the Spaniards employ the very same symbol as a guttural. Thus in the geographical names Xeres, Xalapa, Mexico, the X has little or nothing of a sibilant character.

The letter X was the last in the Roman alphabet, neither Y nor Z belonging to it, although the majority of Latin grammars include them. On reflection however it will be admitted that the words in which those two letters occur are not really part of the Latin language, but borrowed from the Greek, as *zephyrus*, *zona*; or from some Eastern source, as *gaza*. Such forms as *lachryma*, *hyems*, *sylva*, are simply errors of modern editors. The Romans themselves wrote *lacruma* or *lacrima*, *hiems*, or rather *hiemps*, and *silva*. But the fact that *x* was the final letter of the Roman alphabet is established by an anecdote in the Life of Augustus by Suetonius (c.88).

The interchanges of *x* with other letters are as follows :—

1. *x* with *c*, as in the double form, already mentioned, of the Latin or Greek preposition *ex* or *ec*.

2. *x* with *s c* or *s k*. See S.

3. *x* with *g*, as in the Latin *augeo* compared with the Greek 'αυξανω, and μιγ-νυμι compared with *mix*, Eng., and *mix-tus*, Latin.

4. *x* with *ps*, as the Latin *exilis* compared with the Greek ψιλος. In the same way we find an illiterate Roman officer writing *ixi* for *ipsi*, and thus too *proximus* is the superlative of *prope*. This change is in fact only another instance of the interchange of *p* and *c*, so common between Greek and Latin. See C.

5. *x* perhaps with *h*. Thus ξενος is probably in the first syllable the equivalent of the Latin *hostis* and *hospes*. See O and N. So again *hasta* is probably connected with the Greek ξεστος.

6. *x* with *z*. Thus in Spanish a *z* is found where the Latin has an *x*. For example, the Latin words *crux*, *pax*, have become in Spanish *cruz*, *paz*, whence the names of the American towns, *Vera Cruz* and *La Paz*.

XANTHAMYLAMIDE. [CARBAMIC ACID. *Sulphocarbanate of amyl.*]

XANTHAMYLIC ACID. *Amyldisulphocarbonic acid* ($C_{12}H_{12}O_2S_4 = C_2S_4\left\{\begin{matrix}C_{10}H_{11}O\\HO\end{matrix}\right)$. Xanthamylate of potash is formed on treating a solution of potash in amylic alcohol with bisulphide of carbon until alkaline reaction no longer manifests itself: the salts then crystallises out in plates; it is soluble in alcohol or ether, gives precipitates of xanthamylates with most metallic solutions, and when acted upon by hydrochloric acid yields up its xanthamylic acid.

Xanthamylic acid is an oily liquid, colourless when quite pure, but generally of a yellow tint; it has a pungent disagreeable odour, reddens litmus paper, is heavier than water, burns with a luminous flame, and is readily decomposed by water.

XANTHEIN. A yellow colouring matter contained in flowers. It is extracted by cold alcohol from the petals of yellow dahlias. Xanthein is soluble in water, alcohol, and ether, but does not crystallise from any of these solutions. Alkalies communicate to it a very rich brown colour. It communicates a brilliant yellow to tissues, and unites with most metallic bases forming yellow or brown lakes.

XANTHELENE. [XANTHIC ACID.]

XANTHENE. *Xuthene, Melene.* An unimportant and problematical derivative of hydropersulphocyanic acid.

XANTHIAN MARBLES, the designation given to a collection of architectural and sepulchral remains, from their having been chiefly found in the city of Xanthus in Lycia, a province of Asia Minor. [LYCIA, in GEOG. DIV., col. 638.] They were for the most part obtained by Sir Charles Fellows, during researches conducted at the expense of the British government in the years 1842-46, and are now deposited in the Lycian gallery of the British Museum.

The Xanthian marbles comprise sculptural remains which are believed to range in date from the conquest of Xanthus by the Persians, B.C. 545, to the period of the Byzantine empire, and vary considerably therefore in character and value. The oldest and most important are the rilievi from what is known as the Harpy Tomb, which stood near the theatre at Xanthus. This tomb was found almost entire, and consisted of a solid rectangular shaft 17 feet high, surmounted by a small chamber. The friezes on the sides of this pedestal exhibit so much refinement of feeling, combined with an almost austere purity of style, that it may be doubted whether they do not belong to a period antecedent to the Persian invasion, and are not the work consequently of the descendants of the Grecian colonists, before their taste was vitiated by Persian influence. The date usually assigned to them is about 500 B.C.

The tomb has acquired its name from four figures of similar design on the four extremities of its north and south sides, which resemble the Harpy of the ancients. The head is that of a female, the breast is exposed, and the body, which terminates with the trunk, has wings and a tail like a pigeon's; from under the wings comes a bird's claw, clasping the legs of a child, which is carried in the bosom of the figure. They are all flying upwards and outwards from the middle of each group, and are carrying off female children. There was no inscription on the tomb, which, from the flying figures carrying off the children, is supposed to allude to the story of Pandarus, king of Lycia; these figures being the harpies carrying away the daughters of Pandarus. (Homer, 'Odyssey,' b. xx.) Besides these there are seated figures, probably deities, and other personages from the Greek mythology. The figures are about three feet high, and the four compartments, about nine feet in length, form the top of the tomb, and are elevated about twenty feet above the ground upon a square shaft or pedestal of gray stone, and roofed with two flat stones of a similar material; the bas-reliefs are in white marble.

Close to this tomb stood another similar tomb of the same dimensions, entirely covered with Lycian characters. These Xanthian tombs extend over several miles of country.

Another extremely interesting series consists of a broad and a narrow frieze, and various architectural members of a remarkable Ionic structure, the purpose of which is not determined, but of which there are in the room an excellent model, according to the restoration proposed by Sir C. Fellows, under whose direction it was made, and a picture showing the appearance of the spot prior to the excavations. The friezes represent contests between the heavily-armed Greek soldiers and more lightly equipped Asiatics; the siege of a city, and a sally of the besieged; and a Persian satrap receiving a deputation. The subject referred to is usually considered to be the conquest of Lycia by the Persians under Harpagus, and the building to have been the tomb of Harpagus, or a memorial to his honour, and to have been erected in the 4th century, B.C. By some, however, the bas-reliefs are supposed to represent the suppression of the revolt of the Lycians, B.C. 387. Be that as it may, the sculptures are thoroughly Persian in character, and both in subject and style recal to the memory similar subjects among the Assyrian rilievi. Another series of bas-reliefs, part of the tomb of one Paiafa, a satrap of Lycia, has representations of warriors fighting, while on each side of the tomb was an armed figure in a quadriga. Other slabs, statues, and sculptured fragments, of a more or less debased style, carry down the illustrations of Lycian art to the period mentioned above.

(Fellows' *Journal, &c.; Account of Discoveries in Lycia; Account of the Ionic Trophy Monument excavated at Xanthus;* and *Essay on the Relative Dates of the Lycian Monuments in the British Museum;* Scharf, *Observations on the Sculptures seen on the Monuments of Ancient Lycia;* Gerhard, *Archäol. Zeitung*, 1845; *Official Synopsis of British Museum.*)

XANTHIC ACID. *Sulphocarbovinic acid. Ethyldisulphocarbonic acid* $\left(C_6H_6O_2S_4=C_2S_4\left\{\begin{matrix}C_4H_5O\\HO\end{matrix}\right.\right)$. Xanthate of potash is formed on treating an alcoholic solution of potash with bisulphide of carbon until all alkaline reaction be neutralised; the mixture artificially cooled deposits colourless prismatic crystals, which are very soluble in water or alcohol, but insoluble in ether; dilute hydrochloric acid decomposes them and sets free xanthic acid.

Xanthic acid is so named from ξανθός, *yellow*, because it gives a yellow precipitate with salts of copper. It is oily; heavier than, and insoluble in, water; has an acid, astringent, and bitter taste, and pungent odour. Heated to ebullition it is decomposed into alcohol and bisulphide of carbon, and is very inflammable. It strongly reddens litmus paper and decomposes alkaline carbonates with effervescence.

The *xanthates* are, with the exception of xanthate of potash, unimportant. The copper salt, already referred to, seems to be accompanied by a crystallisable compound. *Xanthelene* (xanthate of ethyl), an oily liquid, is also occasionally formed at the same time, but possibly is a product of the decomposition of the crystalline body.

XANTHIC OXIDE. [URIC GROUP.]

XANTHIN. This name has been applied to two distinct bodies, namely, to a colouring matter contained in madder [MADDER, COLOURING MATTERS OF] and to the yellow colouring matter of flowers. The latter is best extracted by treating the sunflower with boiling absolute alcohol; on cooling, the alcohol deposits the whole of the xanthin, which is of a beautiful yellow colour, insoluble in water, but soluble in hot alcohol and water. It is an uncrystallisable resinous substance.

XANTHO-COBALTIA (Co_2O_3, $5NH_3$, NO_2). An ammoniacal base containing cobalt. It is obtained in the state of sulphate by transmitting a rapid current of nitrous acid through an ammoniacal solution of sulphate of cobalt, keeping the liquid alkaline by the occasional addition of ammonia. The sulphate of xanthocobaltia has the formula

$$Co_2O_3,\ 5NH_3,\ NO_2,\ 2SO_3+HO.$$

The nitrate and chloride have the following formulæ:—

Nitrate . . . $Co_2O_3,\ 5NH_3,\ NO_2,\ 2NO_5+HO$
Chloride . . . $Co_2OCl_3,\ 5NH_3,\ NO_2+HO$

[COBALT.]

XANTHOGENAMIDE. [CARBAMIC ACID. *Sulphocarbamate of ethyl.*]

XANTHOPENIC ACID. [OPIUM, ALKALOIDS OF, *Opiammon.*]

XANTHOPHYLL. It is well known that in autumn the foliage of many forest-trees becomes of a bright yellow colour, which, according to Berzelius, is owing to the replacement of the green colouring-matter of the leaves, or *Chlorophyll*, by a peculiar yellow colouring-matter which he calls *Xanthophyll*. The properties of this are, that it is a fatty substance of a deep yellow colour, which melts between 100° and 120° Fahr.: it is insoluble in water, but dissolves copiously in alcohol and ether; its solution exposed to air and light is rapidly bleached; alkalis dissolve it sparingly.

XANTHOPICRITE. *Xanthopicrin.* A substance contained in the bark of the *Xanthoxylum Clava-Herculis, L.*, employed in the Antilles as a febrifuge. It crystallises in greenish-yellow silky needles, which are bitter and astringent, readily soluble in alcohol, slightly so in water, and insoluble in ether. It possesses neither acid nor alkaline qualities.

XANTHOPROTEIC ACID ($C_{34}H_{26}N_4O_{14}$?). According to Mulder, this acid is formed when albumen or any other protein compound is digested in nitric acid; these dissolve with the escape of nitrogen gas, and yield a yellow-coloured solution, while oxalic acid and ammonia are formed.

Two equivalents of protein, 1 of water, and 2 of nitric acid, yield 3 of oxalic acid, 2 of ammonia, and 1 of xanthoproteic acid. After being washed with boiling water, this acid exists as a tasteless orange-yellow powder, which combines with acids as perfectly as with bases; its compounds with the latter dissolve in water, and give dark-red coloured solutions.

XANTHORHAMNIN. [CHRYSORHAMNIN.]

XANTHOXYLENE. [ESSENTIAL OILS; *xanthoxylum.*]

XANTHOXYLIN. [ESSENTIAL OILS; *xanthoxylum.*]

XIPHIAS (constellation). [DORADO.]

XUTHENE. [XANTHIN.]

XYLENE. [XYLOLE.]

XYLIDINE. [XYLOLE.]

XYLITE ($C_{12}H_{12}O_2$?). According to Gmelin, when commercial pyroxylic spirit is submitted to distillation from chloride of calcium, a vapour rises, which condenses into a liquid, which he calls *xylite*.

The properties of this substance are, that it strongly resembles alcohol; its odour is like that of ether and agreeable, and its taste is empyreumatic; its specific gravity is 0·816, and its boiling-point about 143° Fahr.: it is miscible with water, and burns with a white flame. The density of its vapour was found by experiment to be 2·177; by theory it should be rather lighter.

With acids xylite produces ethereal compounds, which have not been minutely examined; and by partial decomposition it gives rise to *xylitic acid, xylite naphtha, xylite resin*, and *xylite oil;* these substances, however, have not hitherto been very particularly subjected to experiment, and the whole of these bodies require re-investigation.

XYLITE NAPHTHA. [XYLITE.]

XYLOIDIN. *Pyroxam* or *nitramidine* ($C_{12}H_9(NO_4)O_{10}$?). A substance allied to pyroxylin. [GUN-COTTON.] Starch is dissolved in nitric acid of sp. gr. 1·5, and the solution immediately diluted with water: a white, tasteless substance is then precipitated which is the body termed pyroxylin. It is insoluble in water, alcohol, or ether, and when heated to 356° Fahr. burns rapidly, after the manner of gun-cotton. It explodes when smartly struck on an anvil by a hammer, but less powerfully than gun-cotton. It also leaves much carbonaceous residue when burnt, and, unlike pyroxylin, is easily soluble in nitric acid. Protosalts of iron reliberate starch from xyloïdin.

XYLOLE ($C_{16}H_{10}$). *Xylene.* A volatile liquid hydrocarbon homologous with benzole, &c., of the series C_nH_{n-6}. It is one of the constituents of the oily impurities contained in commercial wood-spirit, and which separate on the addition of water. It is purified by agitation with concentrated sulphuric acid and fractional distillation.

Xylole is a limpid colourless fluid; boiling point 259° Fahr. Fuming nitric acid converts it into *nitro-xylole*, a yellow oil heavier than water and of an odour somewhat resembling, but less pleasant than, that of nitrobenzole. Nordhausen sulphuric acid slowly combines with it and forms colourless, deliquescent, acicular crystals of *sulfo-xyloic* or *xylenylsulphurous acid* ($C_{16}H_{10}S_2O_6$). Nitric acid acts upon the latter compound to form *nitro-sulfo-xyloic* or *nitro-xylenylsulphurous acid* ($C_{16}H_9(NO_4)S_2O_6$).

Xylidine ($C_{16}H_{11}N$). This alkaloid much resembles its homologues, toluidine, &c. It is produced by the reaction of nitroxylole and sulphide of ammonium. When pure it is almost colourless, but becomes purple on exposure to air and finally resinifies. It turns red litmus paper blue; boiling point 416° Fahr.

XYLORETIN ($C_{40}H_{33}O_4$?). A fossil resin found in Danish peat. It crystallises in confused prisms, which are insoluble in water, but very soluble in alcohol and ether.

Y

Y has found its way into the alphabets of Western Europe through the later Latin alphabet from the Greek. The oldest form of the Greek character appears to have had no vertical stroke, but to have been precisely the same as the English or Roman V, so that the small character *v* differed from the other form only in the usual substitution of a curve for an angle. We have said that the letter Y belonged only to the *later* Roman alphabet. This fact has been already remarked upon under X; and an argument in confirmation of what is there asserted may be drawn from the consideration that the Romans already possessed in their V the representative of the Greek letter. How then, it may be asked, was it that they subsequently adopted this letter? The answer would probably be this—that the Greek character had changed its power from the original sound of *oo*, such as is still represented by the Italian *u*, to a sound probably like that of the French *u*, or even to a weak *i*. If we traced the Greek letter Y or V still farther back, we should perhaps arrive at the opinion that it grew itself out of a carelessly written O. The Hebrew character which corresponds to O, namely, ע, already exhibits the opening above, just as the Hebrew ט does, compared with the Greek Θ. So too the English often write a capital O without joining the circle at the top. To these considerations may be added the fact that the Hebrew alphabet, which ended with a T, contains no other equivalent for the Greek Υ: and again the Etruscans had but one character, V, without any O. That the introduction of the character Y into Latin words has been carried beyond the proper limit has been already remarked [X]; and we would add to what has been there said, that in the well-known Medicean Manuscript of Virgil there is something suspicious in the fact that this letter always overtops the other letters in such a manner that the vertical shaft is of the same height with them; and thus it is possible that the horns, if we may so call them, were attached by a subsequent hand, the manuscript until then having merely an I. (See Foggini's reprint of that Manuscript, and the second line of the copperplate facsimile of the same (amadryades) in Burmann's 'Virgil,' vol. i., facing p. xxxvi. of the preface.)

In the English language there is a great tendency to use this letter at the end of words. This has probably arisen from our habit of giving a tail to the last unit of the Roman numerals, preferring *ij, iij, vj, vij*, &c.; so that to please the eye and give a sort of finish to a word, *say, boy, they*, were preferred to *sai, boi, thei*. Before we leave the form of the letter, it may be observed that in *y*^{e}, *y*^{t}, for *the, that*, the *y* has been by an easy error substituted for the Anglo-Saxon þ, which had the power of *th*.

The sound of *y*, so familiar to the English at the beginning of words, as in *yes, young, yoke*, was represented in Latin by a mere *i*, which however, when so used, received from the grammarians the distinctive name of *i consonans*. Our modern editors have for the most part substituted for it a *j*. Thus, *iugum*, or rather IVGVM, which is now written *jugum*, commenced with a sound which is commonly held to have been the same with our initial *y* in *yoke*. The insertion of the sound of a *y* before vowels is very characteristic of the Russian language, the alphabet of which has no less than four characters which denote such a sound. The English too have a habit of expressing the sound, though they do not write the letter, whenever a long *u* begins a word, as *union, unity, useful*; so that those who write *an useful contrivance* insert a letter at the end of the first word which no one would pronounce. In Anglo-Saxon the sound of a *y* was commonly represented by an *e* before *a* or *o*, and by an *i* before *e* or *u*, in which cases the allied languages of Iceland, Denmark, and Sweden for the most part employ a *j*. Thus the Anglo-Saxon writes *eorl, Eotaland, eow, Eadward, eahta, beód-an* for *earl, Jutland, you, Edward, eight, to bid*. On the other hand, *iett, iúgoth*, represent *yet, youth*. (Rask's 'Grammar.') In several of these words the initial *y* no longer appears in modern English. But it would be unsafe to infer that the change always takes place in that direction, for one who observes children in their early attempts to speak, will find that many are apt to prefix either a *w* or a *y* to all words beginning with a vowel. Thus we have heard a child pronounce *Uncle, Agnes, apple*—*Yung, Yang, wap*; so that the prefixing a *y* where there was none, is just as possible as to drop a previously existing *y*. The sound of *y* again is heard where the French write *ll* or *gn*, as in *vaillant, agneau*; in the Spanish *ll* or *ñ*, as in *Mallorca, Coruña*; in the Portuguese *lh* or *nh*, as in *filho, Minho*; and in the Italian *gl* or *gn*, as in *figlio, agnello*. For the interchange of *y* with *g*, see G; for the use of *z* with the sound of *y*, see Z; lastly, for the connection between the sounds of *j* and *y*, see J and Z.

YACHT. A vessel used for pleasure on the water. The love of yachting indicates a prominent feature of the national character. Clubs and societies are formed all round the coasts of Great Britain, many of them possessing some of the finest specimens of naval architecture. Of late years pleasure trips to distant countries have much improved the style and class of vessels used for recreation. Wealthy owners have often encouraged novel appliances, and assisted in nautical experiments, which would otherwise have fallen into neglect.

There are two distinct species of yachts, which are recognisable at sight, namely: the mere racer, with enormous spars and sails, and deeply ballasted hull, with the finest lines imaginable, but sacrificing space and comfort to speed; and the elegant, well-proportioned, commodious, safe, but well-manned and fast-sailing family yacht, able to encounter the wars of the elements in any part of the globe. Those accustomed to river navigation only, and who desire to consult the models of thorough "sea-boats," will do well to examine some of the Cowes pilot cutters, and the pilot schooners of the Mersey. Every precautionary appliance needed for the roughest and nicest practice of seamanship may be found fitted in them with studied compactness. Our principal rivers and estuaries in the summer months abound with beautifully-modelled small craft, while the Solent pre-eminently offers the spectacle of a brilliant fleet, owned as well by the wealthy commoner as by the peer.

YARD. [Weights and Measures.]

YARN. [Thread.]

YEAR. Much connected with this article is to be found in Kalendar, Periods of Revolution, Moon, Sun, Chronology, Time, &c. We here confine ourselves to matters of useful reference connected with the length and subdivisions of the year, omitting discussion of points of history, which do not directly bear upon chronological reckoning.

The year is, roughly speaking, the period of time in which the sun makes the circuit of the heavens, and the seasons of agriculture run through their course.

A *sidereal* year is the period in which the sun moves from a star to the same again; that is, the interval between the two times when the sun has the same longitude as a given star. The mean period is 365·2563612 mean solar days, or 365^{d} 6^{h} 9^{m} 9^{s}·6.

A *tropical* or *civil* year is the time in which the sun moves from the vernal equinox to the vernal equinox again; and its mean length is 365·2422414 mean solar days, or 365^{d} 5^{h} 48^{m} 49^{s}·7.

The *anomalistic* year is the time in which the sun moves from its perigee (or nearest point to the earth) to its perigee again; and its length is 365·2595981 mean solar days, or 365^{d} 6^{h} 13^{m} 49^{s}·3.

The tropical year is shorter than the sun's actual orbital revolution, or the sidereal year, because the equinox moves slowly backwards [Precession], and therefore the sun meets it again before it arrives at the point at which it met it last. The anomalistic year is longer than the sidereal year because the perigee moves forward, and the sun is not nearest to the earth until it has passed the longitude at which it was nearest to the earth before. The *tropical* year is *the* year, when no distinctive term is applied; for the passage of the sun from the southern to the northern side of the ecliptic is the positive phenomenon on which the seasons *depend*, though it may not be correct to say that it is then that the succession of seasons *begins*.

The anomalistic year does not, and from the theory of gravitation most probably cannot, vary by any quantity which the human senses could appreciate; but the sidereal and tropical years vary very slowly in length. The reason is twofold. In the first place, the amount of the yearly precession of the equinoxes is slowly increasing; so that the part of the orbit by which the equinox moves backwards to meet the sun becomes greater, or the duration of the year less. In the second place, the gradual motion of the equinox, combined with that of the perigee, brings the part of the orbit which the sun is saved from performing by the recession of the equinox into different places with respect to the perigee in successive years; so that the excepted portion is in different years what would have been described in different times. The second consideration affects the sidereal year as well as the tropical; but since in both cases the effect is very small and slow, a few seconds in a thousand years, there is no occasion to do more than point it out in an article like the present. Laplace makes the tropical year to be 13 seconds shorter than it was in the time of Hipparchus.

The excess of the tropical year over 365 days has been given by different astronomers as follows:—

	h.	m.	s.
Euctemon and Meton	6	18	57
Hipparchus and Ptolemy	5	55	12
Hindus	5	50	30
Albatenius	5	46	24
Walther	5	48	50
Tycho Brahe	5	48	45
Delambre	5	48	51·6
Laplace	5	48	49·7

Whether the present length of the tropical year can be said to be determined within a second, we cannot collect from the writings of astronomers. The method of determining this length is by carefully observing solstices or equinoxes (that is, times when the sun is in the solstices or equinoxes) at distant periods, and taking the mean year from the whole interval elapsed. Unless that interval were a whole revolution of the solar perigee with respect to the equinox, the real mean tropical year could not be determined, from observation alone, so well as it might be.

The civil year must, for convenience, begin with a day, and contain an exact number of days. But any exact number of days would have the disadvantage of the old Egyptian year [Sothiac Period], namely, that the seasons would be thrown into all parts of the year in succession. Those who lived in the intense heats of March (when that month is near the autumnal equinox) would read old poets who describe the spring as about to arrive in that month, or allude to the past winter, and that before the poets would have become properly ancient: this alone would be worth avoiding. Of the mode of doing it we shall presently say more; but in the meanwhile we have to observe, that it has always been the greater source of difficulty to combine the revolutions of the moon with those of the sun.

The Jewish, Christian, and Mohammedan religions all regulate their sacred anniversaries more or less by the moon. Various nations have constructed their years on the lunar revolution, though most of them have accommodated their years to the solar year by intercalated months. Now, the time between two new moons (that is, the average time) is 29·5305887 days, or about 29½ days. If, then, months were made alternately of 29 and 30 days, 12 months would contain 354 days, and 11¼ days would be necessary to complete the Julian year of 365¼ days. This would amount to more than a month in three years. Taking the most exact values both of the lunation and the solar year, and applying the method in Fractions, Continued, it will be seen that the year contains, over and above 12 lunations, something less than 3 lunations in 8 years; more exactly, something more than 4 lunations in 11 years; more exactly, something less than 7 lunations in 19 years; more exactly still, something more than 123 lunations in 334 years, less than 130 in 353, more than 253 in 687, less than 1395 in 3788. Taking the Julian year, the above figures should be changed into less than 3 out of 8, more than 7 out of 19, less than 171 out of 464. This excess of 7 lunations in 19 years, which varies very little from the truth, whether as to the real, Julian, or even Gregorian year, is the foundation of the celebrated Metonic cycle [Meton, in Biog. Div.], which, among the Greeks and all who have derived knowledge from them, has always been the foundation of the lunisolar calendar. It is now well understood that the Metonic moon, and not that of the heavens, is the referee in the settlement of religious festivals; that is to say, a moon moving uniformly at such a rate as to make 235 lunations in 19 calendar years.

Owing to the alternate acceleration and retardation of the sun's motion in its orbit, the lengths of the four astronomical seasons are different, as follows :—

	d.	h.
From vernal equinox to summer solstice . .	92	22¼
From summer solstice to autumnal equinox . .	93	13½
From autumnal equinox to winter solstice . .	89	16¾
From winter solstice to vernal equinox . . .	89	1¼

We shall now state the principal facts connected with the years of the nations who are most connected with history.

The Jews, from the time of their departure from Egypt, began their year with the vernal equinox in all religious reckoning, retaining the old beginning, which was at the autumnal equinox, in all civil affairs. In both cases they reckoned from the new moon near the equinox. By making twelve months in the year, each of 29 or 30 days, with an intercalary month once in three years, they secured themselves from the necessity of any but an occasional alteration. They might have gradually allowed the beginning of the year to slide away from the vernal equinox, but this their rites prevented them from doing, since the sacrifices required the offering of various specimens of agricultural produce, dependent upon season, at specified times of the year. The necessity of being provided with young lambs, for instance, at the Passover, obliged them to keep this feast at one time of the solar year, and fixed it at the full moon following the vernal equinox. How they managed their calendar in the first instance, does not appear; but as we know they once depended upon catching sight of the new moon to settle the beginning of the month, and only used 29 or 30 days when they missed their object, we must infer that they were in the habit of making corrections frequently, and at short notice; which could be done, as remarked by the editor of the 'Art de vérifier les Dates,' while they were in possession of Palestine, and within reasonable distance of each other. There is not any trace of astronomy in the old Jewish writings, nor reason to infer that they brought any knowledge of it from Egypt. But during the Captivity they acquired from the nations among whom they were thrown, either a period of 84 years or knowledge to construct one. Several of the Fathers mention this Jewish period, and state that it had long been used by them. It has the appearance of a CALIPPIC PERIOD of 76 years all but a day, with the period of eight years added, on the supposition that the making of three intercalary months in the additional eight years would have an error of a contrary kind from this contained in the Calippic period. But this is not the case; and 84 years is really not so near to an exact number of lunations as 76 years all but a day. Some of the early Christians used this period, and thereby contributed to the confusion on the subject of Easter.

The modern Jewish calendar is regulated by the cycle of 19 years, and its lunar years contain various adjustments which refer to the religious ceremonies. Their present usages date from A.D. 338, according to their own account. They have also a value of the length of a lunation $29^d\ 12^h\ 44^m\ 3^s$, which is within a tenth of a second of the truth. This has been stated as of extraordinary correctness by those who forget that the average month is much more easily found than the year. Hipparchus and Ptolemy had $29^d\ 12^h\ 44^m\ 3\frac{1}{3}^s$; reject the fraction, as was so often done, and we have the Jewish value; and as it happens that Ptolemy and Hipparchus had got just a little more than the fraction too much, this saving of trouble is an accidental correction. There is no accompanying value of the sun's motion more correct than that implied in the Julian year. On the Jewish calendar, see the 'Art de vérifier les Dates,' vol. ii., p. 113, the 'Jewish Calendar for 64 Years,' by E. H. Lindo, 1838, 8vo, which goes up to A.D. 1901, and also the Hebrew work, published with a Latin translation by Sebastian Munster, 'Kalendarium Hebraicum,' Basel, 1527.

The Hebrew months, as commonly spelt in English, are as follows :— opposite to them are written the names of the English months in which they severally most frequently begin, with their number of days :—

Nisan, or Abib	March,	30	days.
Jyar, or Zif	April,	29	,,
Sivan	May,	30	,,
Thammuz	June,	29	,,
Ab	July,	30	,,
Elul	August,	29	,,
Tisri	September,	30	,,
Marchesvan, or Bul	October,	29 or 30	,,
Chisleu	November,	29 or 30	,,
Thebet	December,	29	,,
Sebat	January,	30	,,
Adar	February,	29	,,
Veadar (intercalary) . . .	March,	29	,,

See an account of these months under their several titles.

For the Egyptian year, see SOTHIAC PERIOD.

The twelve months of the Athenian lunar year bear the following names; but there is a slight difference of opinion about the order in which they come, some putting Μαιμακτηριων before Πυανεψιων, and some after it :—

Ἑκατομβαιων,	30 days.	Πυανεψιων,	30 days.
Μεταγειτνιων,	29 ,,	Ποσειδεων,	29 ,,
Βοηδρομιων,	30 ,,	Γαμηλιων,	30 ,,
Μαιμακτηριων,	29 ,,	Ἀνθεστηριων,	29 ,,
Ἐλαφηβολιων,	30 days.	Θαργηλιων,	30 days.
Μουνυχιων,	29 ,,	Σκιροφοριων,	29 ,,

The intercalary month was a second Ποσειδεων of 30 days. It is said that anciently there were 30 days in every month, but that Solon first established the alternation of 30 and 29 days, and called the last day *ἕνη καὶ νέα*, old and new (moon). The shorter months were called hollow (*κοῖλοι*), the longer months full (*πλήρεις*); and these terms have been generally adopted by chronologers. The year in which a month was intercalated was called *ἐμβόλιμος*, or *ἐμβολιμαῖος*, and hence the word embolismic, which is frequently used in the same way.

The month was divided into three decads, the first two of ten days each, the third of ten or nine. The first day was *νουμηνία*, the second was *δευτέρα ἱσταμένου μηνός*, and so on. The eleventh was *πρώτη μεσοῦντος μηνὸς*, or *πρώτη ἐπὶ δεκάδι*, and so on to the last, which was *εἰκάς*. The twenty-first day was *πρώτη ἐπ' εἰκάδι*, and so on; the thirtieth was *τριακάς*. But the third decad was also reckoned by counting backwards from the new moon, thus: the twenty-first day was *δεκάτη*, or *ἐνάτη φθίνοντος μηνὸς*, according as there were ten or nine days in the decad. The last day, whether twenty-ninth or thirtieth, was *ἕνη καὶ νέα*.

There is some doubt whether originally the first of Hecatombæon was the day of the new moon nearest to the summer solstice, or next after it: this must have depended on the mode of intercalation. It is enough for most purposes to know that the Attic year began near the summer solstice. (Clinton, 'Fast. Hellen.,' Introduction.)

As to the intercalations, there is an old period mentioned of two years (*διετηρίς*), with an intercalary month of 30 days. This was also called *τριετηρίς*, because the intercalation was in every *third* year, including that of the former intercalation. This year was, with respect to the sun, more than 7½ days too long. There was also a tetra-eteris, but the first respectable period was the octa-eteris of Cleostratus, in which three months of 30 days each were intercalated in eight years, namely, in the third, fifth, and eighth. The average year of this period was wrong by 1½ hours with respect to the sun, and 1½ days with respect to the moon. The Metonic and Callippic periods followed (B.C. 432 and 330.) The latter was but little used compared with the former, which intercalated seven months in nineteen years. [METON, in BIOG. DIV.; PERIODS OF REVOLUTION.] It is not certain what the years of intercalation were.

The complete Roman calendar, as it stood immediately after the edict of Augustus, correcting the use which had been made of the edict of Julius Cæsar, is as follows :—There are twelve months, Januarius, Februarius, Martius, Aprilis, Maius, Junius, Julius, Augustus, September, October, November, December. The first of each month is its kalends, Kalendæ Januariæ, Februariæ, &c. The number of days in each month is well known by the old rhyme. The 13th of some months, the 15th of others, is called the day of the Ides (Idus); and the ninth day before the Ides, inclusive, is called the Nones (Nonæ); and every day is reckoned by its position with respect to the next simply denominate day, be it Kalends, Nones, or Ides. Thus the third day before the Nones of January, the day of the Nones itself counting as one, is *ante diem tertium Nonas Januarius*—a singular mode of speech, which does not appear to have been fully explained. It is generally rendered as if it were *diem tertium ante Nonas Januarius* (the third day before the Nones of January). These designations are usually written in a contracted form in the manuscripts, and these contractions are usually all that are to be found in chronological works. (See Gellius, iii. 2.)

	Januarius.	Februarius.	Martius.
1	Kal. Jan.	Kal. Feb.	Kal. Mart.
2	iv. Non. Jan.	iv. Non. Feb.	vi. ,,
3	iii. ,,	iii. ,,	v. ,,
4	Prid. Non. Jan.	Pridie Non. Feb.	iv. ,,
5	Non. Jan.	Non. Feb.	iii. ,,
6	viii. Id. Jan.	viii. ,,	Prid. Non. Mart.
7	vii. ,,	vii. ,,	Non. Mart.
8	vi. ,,	vi. ,,	viii. Id. Mart.
9	v. ,,	v. ,,	vii. ,,
10	iv. ,,	iv. ,,	vi. ,,
11	iii. ,,	iii. ,,	v. ,,
12	Pridie	Prid. Id. Feb.	iv. ,,
13	Id. Jan.	Id. Feb.	iii. ,,
14	xix. Kal. Feb.	xvi. Kal. Mart.	Prid. Id. Mart.
15	xviii. ,,	xv. ,,	Id. Mart.
16	xvii. ,,	xiv. ,,	xvii. Kal. April.
17	xvi. ,,	xiii. ,,	xvi. ,,
18	xv. ,,	xii. ,,	xv. ,,
19	xiv. ,,	xi. ,,	xiv. ,,
20	xiii. ,,	x. ,,	xiii. ,,
21	xii. ,,	ix. ,,	xii. ,,
22	xi. ,,	viii. ,,	xi. ,,
23	x. ,,	vii. ,,	x. ,,
24	ix. ,,	vi. ,,	ix. ,,
25	viii. ,,	v. ,,	viii. ,,
26	vii. ,,	iv. ,,	vii. ,,
27	vi. ,,	iii. ,,	vi. ,,
28	v. ,,	Prid. Kal. Mart.	v. ,,
29	iv. ,,		iv. ,,
30	iii. ,,		iii. ,,
31	Prid. Kal. Feb.		Prid. Kal. April.

	Aprilis.	Maius.	Junius.
1	Kal. April.	Kal. Mai.	Kal. Jun.
2	iv. Non. April.	vi. Non. Mai.	iv. Non. Juni.
3	iii. „	v. „	iii. „
4	Prid. Non. April.	iv. „	Prid. Non. Jun.
5	Non. April.	iii. „	Non. Jun.
6	viii. „	Prid. Non. Mai.	viii. „
7	vii. „	Non. Mai.	vii. „
8	vi. „	viii. „	vi. „
9	v. „	vii. „	v. „
10	iv. „	vi. „	iv. „
11	iii. „	v. „	iii. „
12	Prid. Id. April.	iv. „	Prid. Id. Jun.
13	Id. April.	iii. „	Id. Jun.
14	xviii. Kal. Mai.	Prid. Id. Mai.	xviii. Kal. Jul.
15	xvii. „	Id. Mai.	xvii. „
16	xvi. „	xvii. Kal. Jun.	xvi. „
17	xv. „	xvi. „	xv. „
18	xiv. „	xv. „	xiv. „
19	xiii. „	xiv. „	xiii. „
20	xii. „	xiii. „	xii. „
21	xi. „	xii. „	xi. „
22	x. „	xi. „	x. „
23	ix. „	x. „	ix. „
24	viii. „	ix. „	viii. „
25	vii. „	viii. „	vii. „
26	vi. „	vii. „	vi. „
27	v. „	vi. „	v. „
28	iv. „	v. „	iv. „
29	iii. „	iv. „	iii. „
30	Prid. Kal. Mai.	iii. „	Prid. Kal. Jul.
31		Prid. Kal. Jun.	

	Julius.	Augustus.	September.
1	Kal. Jul.	Kal. Aug.	Kal. Sept.
2	vi. Non. Jul.	iv. Non. Aug.	iv. Non. Sept.
3	v. „	iii. „	iii. „
4	iv. „	Prid. Non. Aug.	Prid. Non. Sept.
5	iii. „	Non. Aug.	Non. Sept.
6	Prid. Non. Jul.	viii. Id. Aug.	viii. Id. Sept.
7	Non. Jul.	vii. „	vii. „
8	viii. Id. Jul.	vi. „	vi. „
9	vii. „	v. „	v. „
10	vi. „	iv. „	iv. „
11	v. „	iii. „	iii. „
12	iv. „	Prid. Id. Aug.	Prid. Id. Sept.
13	iii. „	Id. Aug.	Id. Sept.
14	Prid. Id. Jul.	xix. Kal. Sept.	xviii. Kal. Oct.
15	Id. Jul.	xviii. „	xvii. „
16	xvii. Kal. Aug.	xvii. „	xvi. „
17	xvi. „	xvi. „	xv. „
18	xv. „	xv. „	xiv. „
19	xiv. „	xiv. „	xiii. „
20	xiii. „	xiii. „	xii. „
21	xii. „	xii. „	xi. „
22	xi. „	xi. „	x. „
23	x. „	x. „	ix. „
24	ix. „	ix. „	viii. „
25	viii. „	viii. „	vii. „
26	vii. „	vii. „	vi. „
27	vi. „	vi. „	v. „
28	v. „	v. „	iv. „
29	iv. „	iv. „	iii. „
30	iii. „	iii. „	Prid. Kal. Oct.
31	Prid. Kal. Aug.	Prid. Kal. Sept.	

	October.	November.	December.
1	Kal. Oct.	Kal. Nov.	Kal. Dec.
2	vi. Non. Oct.	iv. Non. Nov.	iv. Non. Dec.
3	v. „	iii. „	iii. „
4	iv. „	Prid. Non. Nov.	Prid. Non. Dec.
5	iii. „	Non. Nov.	Non. Dec.
6	Prid. Non. Oct.	viii. Id. Nov.	viii. Id. Dec.
7	Non. Oct.	vii. „	vii. „
8	viii. Id. Oct.	vi. „	vi. „
9	vii. „	v. „	v. „
10	vi. „	iv. „	iv. „
11	v. „	iii. „	iii. „
12	iv. „	Prid. Id. Nov.	Prid. Id. Dec.
13	iii. „	Id. Nov.	Id. Dec.
14	Prid. Id. Oct.	xviii. Kal. Dec.	xix. Kal. Jan.
15	Id. Oct.	xvii. „	xviii. „
16	xvii. Kal. Nov.	xvi. „	xvii. „
17	xvi. „	xv. „	xvi. „
18	xv. „	xiv. „	xv. „
19	xiv. „	xiii. „	xiv. „
20	xiii. „	xii. „	xiii. „
21	xii. „	xi. „	xii. „
22	xi. „	x. „	xi. „
23	x. „	ix. „	x. „
24	ix. „	viii. „	ix. „
25	viii. „	vii. „	viii. „
26	vii. „	vi. „	vii. „
27	vi. „	v. „	vi. „
28	v. „	iv. „	v. „
29	iv. „	iii. „	iv. „
30	iii. „	Prid. Kal. Dec.	iii. „
31	Prid. Kal. Nov.		Prid. Kal. Jan.

The intercalary year, when introduced by Cæsar, had the additional day bestowed upon it by doubling the sixth day before the kalends of March (whence the year was called *bissextile*) [BISSEXTILE]: so that the month of February ended thus—

23	vii. Kal. Mart.
24	vi. Kal. Mart. poster.
25	vi. Kal. Mart. prior.
26	v. Kal. Mart.
27	iv. „
28	iii. „
29	Prid. Kal. Mart.

There was thus *ante diem sextum kalendas Martias posteriorem* and *ante diem sextum kalendas Martias priorem*. The general rules of this clumsy calendar are, that the ides are on the 15th of March, May, July, and October, and on the 13th of all the other months: that the nones are always on the eighth day before the ides, according to our mode of counting: that the kalends are always on the first day of the month: and that the intermediate days are numbered as far as numbering is required, backwards from the kalends, nones, or ides, each of these reckoning as one day in counting backwards from it.

The original Roman year is variously stated by historians at twelve and ten months: the latter seems the best supported, and the old year wanted January and February, and had Quinctilis and Sextilis in place of July and August: these two months yielded their names to those of the two emperors who reformed the calendar. Numa or Tarquin introduced what was meant for a lunar year of 355 days. The year is supposed to have been more assimilated to the solar year by the decemvirs; but there is a great deal of discussion upon all these points, which would be quite out of place in anything but an historical article. In the year 45 B.C. the correction made by Julius Cæsar, with the assistance of Sosigenes, was introduced, the preceding year having been lengthened into 445 days, in order probably that the new era might fall at the full moon following the shortest day. The pontifices maximi who came after Julius Cæsar mistook the meaning of his correction; by a bissextile every *fourth* year they thought was meant one every fourth year, counting the last bissextile, according to their interpretation of Cæsar's rule, by which the fourth numbers beginning from 1 were made not 5, 9, 13, &c., but 4, 7, 10, &c. This was corrected by Augustus, when Pontifex Maximus in B.C. 8, who directed that three bissextiles from that date should be omitted (being as many as had been then superadded to Cæsar's calendar in years preceding), and that the mistake should be avoided in future.

No further chronological difficulty occurred until the 3rd century, when disputes about the mode of determining Easter-day began to perplex the Christian world. It is commonly stated that the Council of Nice made that adjustment which lasted until the Gregorian reformation. This is not correct: the council, according to Eusebius and others, only ordained that all Christians should keep Easter on one and the same day. [EASTER.]

The Gregorian reformation (so called; we will not stop to give reasons for our protest against the word) was a consequence of the desire that the seasons should remain in the same months for ever. The Julian calendar gave a year which is too long at the rate of 3 days in 400 years nearly. At this rate, in 24,000 years midsummer and midwinter would have fallen in December and June. It was not so much to avoid this, as to keep the religious festivals in the same part of the year, that is, in the same kinds of weather, that the correction was insisted on by its advocates. The change had been discussed by individuals and even by councils during preceding centuries, and was finally decided on by Gregory XIII., with the authority of the council of Trent. In 1582 the reformation was carried into effect: ten days were struck out of the reckoning, that which would have been the 5th of October being denominated the 15th, so that the days 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 of October, 1582, never existed in Italy and Spain, which accepted the change as soon as it was decreed. Some other countries, as France, which accepted it in the year 1582, but not so early, had to make their changes accordingly. See STYLE for the times of adoption in different countries.

There was one incorrectness about this part of the change, but not of any detriment. The equinox fell, at the time of the Nicene council, on the 21st of March, and the suppression of ten days was meant to make the equinox vibrate between the 21st and 22nd. But in point of fact, the Alphonsine tables, which were consulted, are wrong by a day in this matter, and eleven days should have been suppressed. The consequence is [PERIODS OF REVOLUTION] that the equinox vibrates between the 20th and 21st of March.

Leaving out the parts of the Gregorian correction which relate to Easter, we proceed to the alteration of the mode of intercalation. This is as follows:—Every year whose number is divisible by 4 is leap-year, except only when the number ends with 00, in which case it is not leap-year, except when the preceding figures are divisible by 4. Thus 1900 is not leap-year, but 1600 is. If we take the most recent value of the length of the year, 365·2422414 mean solar days, and apply the method in FRACTIONS, CONTINUED, we shall see that the excess of the real year above that of 365 days is something less than 1 day in 4 years, more than 7 in 27, less than 8 in 33,* more than 39 in 161, and less than 242 in 999. This last excess, 242 days in 999 years, is so very correct, that it is most fortunate that Gregory's advisers did not know it, for they would in that case have adopted it and saddled our world with a most troublesome omission of intercalations for the benefit of posterity of 50,000 years hence. As it is, the excess of 1000 mean Gregorian years above as many of 365 days is 242·5 days: it would have been nearer the truth had it been 242·242 days. Accordingly 1000 mean Gregorian years are too long by about a quarter of a day; more correctly, 3600 years give an error of a day. Delambre proposed that the Anni Domini 3600, 7200, 10,800, &c., should not be leap years, which they are to be in the Gregorian calendar. If the world should last till A.D. 3600, we hope the correction will be called by Delambre's name; if his memory should then have perished, still more will that of the present article, so that there is no use in pressing the point.

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* The Persians are said to have used the intercalation of 8 days in 33 years

The European years have been made to begin at such different periods, that the historical inquirer is frequently puzzled. We have mentioned those which relate to our country in PERIODS OF REVOLUTION. The 25th of December, the 1st of January, the 1st of March, the 25th of March, and Easter, have all been in use.

In regard to the common year as it now stands, there are several things which it will be useful to remember. We can hardly forbear to quote the verses which are so constantly in use, but we will do it from a version of 1596, in an arithmetical work:—

Thirtie daies hath September,
Aprill, June, and November,
Februarie eight and twentie alone,
All the rest thirtie and one.

The common year begins and ends on the same day of the week; leap-year ends on the next day. Thus 1843, not being leap-year, ends on Sunday, as it began; had it been leap-year, it would have ended on Monday. Many of those who call the year 52 weeks are hardly aware that it is 52 weeks and a day, or when leap-year, two days.

To find the day of the month without an almanac, it is very useful to know the first day in each month which has the same name as the first day of the year, as in the following list:—

1st of January, October,
2nd of April, July,
3rd of September, December,
4th of June,
5th of February, March, November,
6th of August,
7th of May,
are of the same name.

Thus in the year 1843 all the days just mentioned are Sundays, the same as the first day of the year. If these days could be connected by some decent doggerel, such as that already quoted, any one who remembers them would only have to bear in mind the name in the week of the first day of the current year, and would thus have a point to start from in every month.

Since the above recommendation was given, such verses as were asked for appeared in the 'Notes and Queries,' as follows:—

"The first of October, you'll find if you try,
The second of April, as well as July,
The third of September, which rhymes to December,
The fourth day of June, and no other, remember,
The fifth of the leap-month, of March and November,
The sixth day of August, and seventh of May,
Show the first of the year in the name of the day.
But in leap-year, when leap-month has duly been reckoned,
These month dates will show, not the first, but the second."

The Mohammedan year is one of twelve lunar months, of 30 and 29 days alternately, the last month, however, having 30 days in intercalary years. To keep the months to the new moons, a cycle of thirty years is used, in which there are eleven intercalated years, being

2, 5, 7, 10, 13, 16, 18, 21, 24, 26, 29,

of the cycle. This makes a very good lunar cycle: it supposes 10,631 days to be an exact number of lunations, which it is within about a hundredth of a day, giving an error of a day in 2500 years. Of course the Mohammedan year is vague, its beginning retrograding through the different seasons of the solar year. The mode given in TURKISH CHRONOLOGY does very well to determine the commencement, except that when the Christian year contains the commencements of two Mohammedan years, the rule will only give one; the other, however, may easily be inferred. When the comparison of dates is to be very close, no easy rule will be sufficient, and recourse must be had either to the list in the 'Art de vérifier les Dates,' to the rule and supplementary tables in the 'Companion to the Almanac' for 1830, or to a sufficient method in De Morgan's 'Book of Almanacs.' The year 1 of the Hegira begins from July 16, 622, and the year 1260 begins January 10, 1844. But from and after the year A.D. 1583 (991 of the Hegira) the 'Art de vérifier les Dates' gives two commencements for every year (the second twelve days later than the first), which are, it says, according to the old calendar and the new one: no mention is made of this distinction, that we can find, in the introduction to that work, nor in other common sources. Our 'Nautical Almanac' gives the commencements according to the new calendar.

The unwise attempt made by the French, during their first revolution, to alter the names and dispositions of the years and months, might now be quietly consigned to oblivion, if it were not that many excellent works bear the revolutionary dates upon their title-pages, and political occurrences are frequently referred to them during the short period of their florescence. The year 1 of this period was made to begin September 22, 1792; each period of four years, or Franciad, had an Olympic or bissextile at its end. The three omitted leap-years of the Gregorian correction were found by the same rule as before, relatively to the years ending with 00: and the 4000th year was not to be leap-year. The year consisted of 12 months of 30 days each, with five sacred days at the end, dedicated to Virtue, Genius, Labour, Opinion, and Reward; the bissextile day being appropriated every fourth year to the renewal of the oath of liberty. For further detail see KALENDAR.

YEAR-BOOKS. [REPORTS.]

YEAST, or FERMENT, a substance which is deposited in an insoluble state during the fermentation of wine, beer, and vegetable juices. This substance, as is well known, is employed to produce fermentation in saccharine solutions. According to Liebig, the insoluble part of yeast does not cause fermentation, for he states that if it be "carefully washed with water, care being taken that it is always covered with water, the residue does not produce fermentation." Neither, according to the same authority, does the soluble part of yeast excite fermentation until it has been allowed to cool in contact with the air, and to remain some time exposed to its action; if in this state it be introduced into a solution of sugar, it produces brisk fermentation.

Yeast is a product of the decomposition of gluten, and when added to a solution of pure sugar, it gradually disappears; but when added to vegetable juices which contain gluten as well as sugar, it is reproduced by the decomposition of the gluten, in the same way as it was originally formed. According to Professor Graham, the action of yeast and all other ferments is destroyed by the temperature at which water boils, by alcohol, by acids, salts of mercury, sulphurous acid, chlorine, iodine, bromine, by aromatic substances, volatile oils, and particularly empyreumatic oils, smoke, and a decoction of coffee; these bodies in some cases combining with the ferments or effecting their decomposition.

Mr. Fownes gives the following as one mode of producing yeast without the aid of a ferment. Wheaten flour and water are mixed to the consistence of a paste, and slightly covered up in a warm place; a sour odour is produced, and carbonic acid gas given off, about the third day; by about the sixth day the odour becomes vinous rather than sour; and then the substance has practically become yeast, or a substitute for it. It may be either used at once, or laid by for future use. In the latter case, it is made into small thin cakes, and dried in the air; when about to be used, the cakes are dissolved. This is nearly equivalent to the ancient mode of making *leaven*. Mr. Cooley describes a mode of making yeast with the aid of a ferment. About ¼ lb. bean-flour is boiled for half an hour in 6 quarts of water. The solution is poured into a vessel; 3½ lbs. wheat-flour is added and stirred in; when cooled down to about 55° Fahr., 2 quarts of beer-yeast are added; and when the mixture has fermented for 24 hours, 7 lbs. of barley-flour or bean-flour is thrown in. The composition is kneaded into dough, made into cakes, and kept in a dry place till wanted for use.

This subject is further illustrated under BREAD; BREWING; FERMENT.

YELLOW. [CALICO-PRINTING; DYEING.]

YELLOW FEVER. [FEVER, YELLOW.]

YELLOW OCHRE. [COLOURING MATTERS.]

YEW, *Economical Uses of.* Nearly every part of the yew tree is applied to some useful purpose. Considered as timber, the wood is hard, compact, of a fine and close grain, flexible, elastic, easy to split, and little affected by atmospheric changes. It varies in tint from orange-red to deep brown, with a hard white sap-wood. Both the real wood and the sap-wood will take a very high polish. It has been found that the wood, when cut into thin veneers before being seasoned, and steeped some months in a pond, took a purple-violet colour. Yew timber takes a long time to dry, but shrinks little during the drying; showing that the moisture contained, though not large in quantity, clings with great obstinacy among the fibres. The fineness of its grain renders it well fitted for cabinet-making purposes, when used as a veneer and polished. The wood is converted by the turner into vases, boxes, and numerous kinds of useful and ornamental articles. Beautifully veined pieces are often obtained from the root and the knots of the branches. Yew is one of the best of all kinds of timber for hydraulic engineering, such as water-pipes, pumps, piles, &c., on account of its power of resisting the action both of air and water. In France axle-trees are often made of yew. The branches are useful for making stakes and hoops; and the young shoots for baskets and ties. Yew, in its power of repelling or resisting vermin, has been recommended as a good material for wooden bedsteads. Before the invention of gunpowder the most important use of the yew was in making bows for the archers. Roger Ascham, in his 'Toxophiles,' published in 1544, states

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very far back in the middle ages; if so, their year was better than the Gregorian.

that "Ewe fit for a bowe to be made on," is the bough, the plant (stem ?), and the bole; the bough is knotty, the plant is apt to break, and the bole, or boole, is pronounced to be the best. He adds, "If you come into a shoppe and fynde a bowe that is small, longe, heavye, stronge, lyinge streighte, not wyndynge, not marred with knotte, gaule, wyndshake, wen, freat, or pinch—bye that bowe of my warrant." The pieces of yew fashioned into bows were from 4 to 6 feet in length. In the time of Elizabeth foreign yew began to grow scarce; it was much preferred to English, insomuch that a bow of foreign yew was valued at 6*s.* 8*d.*, when one of English yew sold for 2*s.* Italy, Turkey, and Spain, were in succession nearly exhausted of yew for this purpose; until at length it became customary to join two pieces together—yew to make the belly of the bow, and ash or elm for the back. At the present day, very few yew trees are found with such a growth of trunk and branches as to be suitable for bows.

The nut yields an oil nutritious for fattening poultry. The dried leaves are sometimes used medicinally, and so are other portions of the tree, but not to any great extent, as there is much poisonous matter secreted by the yew. This poison is one of the causes of the durability of the tree, as it repels the attacks of insects.

YORK, CUSTOMS OF. [WIFE.]

YTTRIA. [YTTRIUM.]

YTTRIUM (Y). This very rare metal occurs as an oxide in several minerals. The names, sources, and properties of these minerals have already been described. [YTTRIUM, in NAT. HIST. DIV.] Yttrium itself is obtained on heating a stratified mixture of chloride of yttrium and potassium in a platinum crucible. After removing the chloride of potassium by water the yttrium remains in dark, iron-gray, shining, pulverulent scales. Under the burnisher it assumes a high metallic lustre; it is not oxidised by steam or at a red heat in the air.

Yttria (YO). Yttrium burns with splendid scintillations in oxygen gas, and yields a white protoxide, or yttria. Yttria is best obtained from the mineral gadolinite, which is digested in aqua regia, the mixture filtered, the filtrate evaporated to dryness, the residue digested in dilute hydrochloric acid, again filtered, the filtrate mixed with large excess of crystallised sulphate of potash, the solution carefully neutralised by ammonia, iron precipitated by succinate of ammonia, and ammonia added in excess to throw down basic sulphate of yttria. The latter by digestion in carbonate of ammonia solution is converted into carbonate of yttria, which by evaporation to dryness and ignition furnishes oxide of yttrium.

Yttria is a white powder of specific gravity 4·842; is inodorous and tasteless; is insoluble in alkalis, but soluble in their carbonates, especially that of ammonia. It occurs as a *hydrate* when precipitated from aqueous solutions of its salts.

Phosphorus, sulphur, iodine, bromine, &c., combine with yttrium to form more or less crystalline colourless salts. *Chloride of yttrium* is formed on passing chlorine over a mixture of yttria and charcoal heated in a porcelain tube; it forms white shining needles. *Sulphate of yttria*, obtained as above indicated, occurs in four-sided transparent prisms which lese water at 176° Fahr. and become milk-white without change of form.

Solutions of yttria are characterised by yielding a white precipitate with ferrocyanide of potassium.

Z

Z, like Y, was only found in the later Roman alphabet [X], from which it has been transferred to the alphabets of Western Europe. In the Greek series of letters it occupied the seventh place, the sixth being the property of the subsequently disused Vau or F. Two questions then arise which deserve an answer: how was it that the Romans gave this letter a place so different from that occupied by the Greek letter? and secondly, how are we to account for the Latin letter G occupying the place which should have been given to Z? We would first observe that the Greeks were surrounded on the north by Slavonic races, with whom an abundance of sibilants has always been in favour, so that the early position in the alphabet of Z need surprise no one. In the second place, we strongly suspect that the genuine sound of the Greek Z in early times was not, as is sometimes stated, that of *sd* or *ds*, for then it would have been a superfluous letter, and would scarcely have appeared so early in the alphabet. We would rather believe that the sound was similar to that of the English *j*, in which case the established interchange of ζ and δι before vowels would be explained. For instance, the form Ζευς in that case would not surprise us alongside of either Διος or *Jupiter, Jovis, &c.*, or of the Italian *Giove*. [D; J.] Next looking to the Roman alphabet we are disposed to contend that the character G was originally employed with the same power. At any rate it was not the equivalent of the Greek Γ, for the third letter of the Roman alphabet, C, as it derived its form from the Greek Γ, merely changing its angle into a curve (a change not unknown to the Greeks themselves, see the tables of the old Greek character under ALPHABET), also possessed precisely the same power, a fact for which we have abundant testimony among the Romans themselves. [C.] But if G originally represented a sound different from the thick guttural Γ, what sound is more likely to have belonged to it than that of our English *j*, when we know that this sound is still current in Italy, although they want a single character to represent it, and, secondly, when it is an undoubted fact that the two sounds are very apt to be interchanged. In our own tongue the very letter in question performs the two offices we are speaking of, in *gender* and *get*, even before the same vowel; and we once met with a child already ten years of age, whose ear and tongue could make no distinction between *goose* and *juice*. In point of fact, the three sounds of *di* before a vowel, of an English *j*, and of our initial *y*, are closely related. Those who read the ballads in Percy's 'Reliques' will find many words where a *z* is used with the power of a *y*, as is still the case in the Scotch names *Dalzel, Mackenzie*, and the Scotch word *capercailzie*, for the English pronunciation of these words is incorrect in giving to them the sound of our English *z*. Nay, in words where an *n* precedes *z*, the sound *ng* is heard: thus *Menzies* is pronounced *Ming-es*. But if the Latin G and the Greek Z had originally the same power, as well as the same place in the alphabetical series, it becomes difficult to believe that the G alone of all the Latin letters did not derive its *form* too from the Greek symbol. Nor is the change so violent as would at first appear. If the Greek Z be written with its oblique shaft from north-west to south-east instead of from north-east to south-west (a supposition having little difficulty in it, if letters were originally pictorial), then the ordinary change from an angle to a curve would bring us to something very near the true Roman G Or again, taking the ordinary Greek Z, the upper horizontal line is already greatly shortened in the cursive character ζ, and in the same way might easily slip into the Latin character. The permutations to which Z is liable have partly been spoken of above, and all of them anticipated in the other letters. [D; G; I; J; S; T; Y.]

ZAFFRE. [COBALT.]

ZEMINDAR, a Persian word which signifies literally a landholder. The word was introduced into Hindustan by the Mohammedans, but it is probable that the office to which it is applied was previously in existence as a part of the system of village organisation which extends throughout the whole of Hindustan. A village in Hindustan is not simply a collection of houses smaller than that of a town; it is a tract of country comprising hundreds (sometimes thousands) of acres of arable and waste land, the inhabitants of which form a sort of corporation, with several officers, each of whom has his distinct duties. The head man of this village corporation is the *potail*, who has at his command the village police. A number of villages form a district, which is larger or smaller according to the number and extent of the villages. The head man of such a district is, in the greater part of Hindustan, called a *zemindar*, and the district itself a *zemindary*. The chief business of the zemindar is to collect the revenues of his district for the government; and that he may do this effectually, the police of the district is under his control. The collectorate, however, is not inseparable from the zemindary; and should the collection be withdrawn, as it occasionally was, the zemindar still remains the head man of the district, and the representative of it to the government.

This account of the zemindars applies to such of the states of Hindustan as were independent of the British government; but a change in the collection of the revenue was made under Warren Hastings in 1772, when the zemindaries were let to the highest bidder for a term of years, the zemindar in possession, however, being preferred when he offered terms which were deemed reasonable.

At length a permanent settlement was made with the zemindars during the government of Lord Cornwallis, in 1791, but was not completely carried out till 1793, forming, as it did, a part of the great financial and judicial reforms introduced by him. The amount to be paid to the government was settled at a fixed rate, in the first instance for a term of ten years; but this was to be rendered permanent if sanctioned by the authorities in England. The zemindars were recognised as proprietors of the soil, and thus have become, in fact, under the British government, what they had not been before, nor are yet under the native governments—landed proprietors of the zemindary. The ryots, all of whom had hereditary rights in their lands, were made over to the zemindars, who too frequently used their new powers oppressively. But in 1822 it was enacted that tenants holding lands by any hereditary or prescriptive rights should not be dispossessed so long as they paid the rents agreed upon, nor should the rents be increased except under certain specified circumstances. The zemindar may dispose of the lands as he thinks fit, and the government does not interfere, so long as the tax is paid.

(Mill's *History of British India*, by Wilson; Malcolm's *Central India*; Jones, *On Rent*.)

ZEND is the name usually given by Parsee priests to the language in which the oldest documents of their religion were composed. [ZEND-AVESTA.] It became current as such in Europe through Anquetil du Perron, who took the word Zend as the name of the language of the Avesta, and Pâzend as that of a corrupted dialect of the Zend. This view, however, has been shown by modern investigations to rest on a mistaken interpretation of a passage of the 'Ormuzd-Yesht,' and of one taken from the 'Ulemâ-i-Islâm'; for it is now certain that Thomas Hyde, whose work on the religion of the old Persians is the first noteworthy essay on this subject, was quite correct in calling Zend and Pâzend not languages, but books. In confirmation of his view, one passage from the Persian Dictionary Burhân-i-Qâti will suffice. It runs as follows:—"Zend is the name of a book which, as Ibrahîm Zerdusht affirmed, had come down from heaven on his account. Others say that it is the name of a book of Abraham; and others again maintain that Zend and Pâzend are two works or parts of this book. Zend is also the name of a Turanian Vezir of Sohrâb, the son of Rustem, who was killed by Rustem. . . . . Pâzend is a commentary on the Zend, and Zend is a book of Zerdusht. Some, however, reverse this definition, by saying that Zend is a commentary on the Pâzend. Again, others maintain that Zend and Pâzend are two books on fire-worship, composed by Ibrahîm Zerdusht; and one author says that Pâzend is a translation of the Zend." (Spiegel, 'Grammatik der Pârsi-sprache,' p. 3.) This passage clearly shows that neither Zend nor Pâzend is the name of a language or dialect, but it likewise gives evidence of the difficulty which even learned Persians evinced in ascertaining the correct meaning of the terms. Nor can we affirm that it is definitely solved by the present results of Oriental philology. Dr. Friedrich Spiegel, who has translated into German the sacred writings of the Parsees, expresses himself to the following effect (Introduction to 'Avesta, die heiligen Schriften der Parsen,' Leipzig, 1852, p. 45):—"Avesta, or, in its older form, Apestâk, means literally the *text*, and is the only correct designation which the later Parsees use for the text of their sacred writings whenever they do not employ the term *dîn*, or 'law,' which word, however, is probably to be taken in a more limited sense. In the invocations of the Yas'na, and elsewhere in the oldest period, the expression *manthrô çpěnto* (that is, the holy speech) occurs for the sacred writings, and this expression has survived under the form of Mânser-çpent. For the language of this oldest period, the Parsees use the expressions, *language of the Manthra, language of the Avesta, divine language*. . . . . But *Zend*, a word not yet sufficiently explained, is reported to designate the commentary on the sacred books, probably the Huzvâresh translation. The language of this translation is called by the Parsees *Huzvâresh*, from the Zend huzaǒthra, that is, bonum sacrificium habens. In connection with Zend we always meet with Pâzend, which word seems to mean the commentary on this translation."

A widely different opinion on this subject is given by another scholar, whose labours have for many years been devoted to an understanding of the old Parsee writings. In a lecture he has recently (on the 1st of March, 1861) delivered at Poona, on the Origin of the Parsee religion, Dr. M. Haug makes the following statement: "I have discovered in most of the books now extant, Yas'na, Visporatu, Vendidad, and Yashts, all the three classes of the ancient religious Persian literature which are spoken of by ancient Mohammedan writers and Persian lexicographers, viz., Avesta, that is, 'original text,' Zend, that is, 'commentary,' and Pâzend, that is, 'explanatory notes of the commentary.' The opinion of the Parsee priests that Zend and Pâzend are names of languages is wholly wrong. These three classes may be best discriminated in the Vendidâd, or code of religious, civil, and criminal laws, customs, and usages, chiefly in its fourth chapter. We find that verse 1 (in Westergaard's edition) is Avesta, being an ancient and scarcely more intelligible law; 2–10, its Zend, or commentary; 11–16, Pazend, or further explanation of the commentary. I shall treat this subject, as well as many other things fully in my 'Essays on the sacred writings and religion of the Parsees,' to be published, as I hope, in the course of this year."

To enter into any speculation on the different periods of the language of the Avesta would be premature, after the confession made by the best living Zend scholars, that they are unable as yet to cope with the considerable difficulties which beset its study. We must, therefore, confine ourselves here to the statement that this language, which—as observed—now passes by the erroneous name of Zend, is one of the Indo-European stock, and bears so great and intimate an affinity to the Sanskrit of the Vedas, that without a knowledge of the latter, we should probably never have arrived at a correct appreciation of the forms of the language of the Avesta. The ingenious comparisons between both languages made by the celebrated Sanskrit scholar, Eugène Burnouf, in his 'Commentaire sur le Yaçna,' have laid the first solid foundation of our present knowledge of Zend, and the place it holds amongst Indo-European languages is best illustrated in the excellent 'Comparative Grammar' of Professor Franz Bopp.

ZEND-AVESTA is the name commonly given to the sacred books of the Parsees, which are ascribed to Zarathustra or Zoroaster; it would be better, however, to call them *Avesta*, which word means *text*, or *original text*, since *Zend* designates the commentary on this text. Parsee tradition tells us that these books originally consisted of twenty-one noaks or large divisions, but that they were destroyed by Alexander the Great, who had all that they contained of medicine and astronomy translated into Greek, and the rest burnt. There is much reason to doubt the accuracy of this report; but whether true or not, it is certain that the Grecian conquest was highly detrimental to the old Parsee religion and its sacred texts, and that the restoration of both did not take place before the elevation to the throne of Ardeshir, the first king of the Sassanian dynasty, or about 220 after Christ. He and the kings of his lineage ordered a collection to be made of all that remained of the sacred Parsee texts, and it is this collection which we possess now under the name of Avesta. But not all of the books deemed sacred by the Parsees can strictly speaking be included under this name. It belongs more particularly to the three which are severally called *Vendidad, Vispered*, and *Yas'na*, whereas the remaining writings are comprised under the denomination of *Khorda-Avesta*, or "small Avesta."

The latter contains short prayers, and especially the *Yashts* or *Yeshts*, hymns addressed to the different genii, on the days which bear their names and are sacred to them, or on the days of those genii who are considered to be the attendants of the former.

The *Vendidad* consists of twenty-two *Fargards* or sections, which treat of cosmogony, and, moreover, may be called the religious and civil code of the old Parsees. The first Fargard relates how Ahura-Mazda (now called Ormuzd), the good spirit, created the several countries and places—sixteen are named—excellent and perfect in their kind, but that *Angrô-Mainyu* (now called Ahriman), the evil or black spirit, created in opposition all the evils which infest these worlds. In the second Fargard, Zarathustra (or Zoroaster) bids Yima announce to mankind the sacred law he had taught him; but Yima refuses compliance with this behest. He then bids him enlarge the worlds and make them prosperous. This time Yima obeys, and carries out the orders given him by Ahura-Mazda. The third Fargard enumerates first the five things which are the most agreeable, then the five things which are the most disagreeable, and afterwards the five things which convey the greatest satisfaction, to this world. It concludes with questions and injunctions of a kindred sort. The fourth Fargard may be termed the criminal code of the Avesta. It enumerates, in the first instance, various offences which are considered to be so grave as to affect not only the person who commits them but also his relatives; and then proceeds to define the punishments incurred by the offender. The eight following Fargards contain injunctions in reference to impurities caused by dead bodies. The thirteenth Fargard begins with the description of two kinds of dogs,—the one created by Ahura-Mazda, the other by Angrô-Mainyu,—the killing of the former being a criminal, that of the latter a meritorious, act; and the remaining part of the book is devoted to the proper treatment of dogs in general, a subject of much importance in a country apparently much infested by wolves, and continued in the fourteenth Fargard, which enumerates also the penalties for injuring dogs. The treatment of young dogs is likewise the subject-matter of the latter part of the fifteenth Fargard, which in its first sections treats of sexual offences, and the bringing up of illegitimate children. The sixteenth Fargard teaches how to treat women in their menses, or when otherwise affected with impurities. Impurities caused by the cutting of hairs and trimming of nails, are the subject-matter of the seventeenth Fargard. The next Fargard is more of a mixed character; it treats of various ceremonies, such, for instance, as are to be practised during the night and at sunrise; and gives injunctions on cleanliness, decency, and moral conduct. The nineteenth Fargard relates how Angrô-Mainyu endeavoured to kill Zarathustra, but how the latter successfully defended himself with the weapons given him by Ahura-Mazda. The evil spirit, it continues, being aware that it had no material power over Zarathustra, then resorted to temptations; but these too were defeated by the prophet, who now resolved to conquer the evil spirit, and for this purpose addressed to Ahura-Mazda various questions on the rites of purification and the condition of souls after death. The twentieth Fargard contains some information about the first man who understood curing disease. The twenty-first Fargard is devoted to the phenomena of the sky and the luminous bodies; it comprises invocations of the clouds, the sun, the moon, and the stars. The last Fargard relates that Angrô-Mainyu having engendered diseases, Ahura-Mazda is compelled to devise remedies against them. In the first place he has recourse to *Manthra-çpenta*, the sacred word, but it is powerless. He then sends Nairyo-sangha to Airyama with the command to produce several useful animals and things for this purpose; and the Fargard, evidently a fragment, concludes with relating that Airyama produced nine kinds of male horses, nine kinds of male camels, nine kinds of oxen, nine kinds of small cattle, and nine kinds of pasture ground.

The form of all these Fargards is nearly always that of a dialogue between Ahura-Mazda and Zarathustra, and the same form is now and then also observed in the two other portions of the Avesta, which differ materially in their contents from those of the Vendidad.

Vispered and *Yas'na* bear prominently a liturgical character. They are invocations of nature, of the deities who are believed to govern its course, of time, seasons, and other objects connected with acts of pious veneration; they also contain views of creation of a speculative kind; in short, they are chiefly the religious and liturgical code of the old Parsee religion, whereas the Vendidad, as observed, is chiefly—though not exclusively—concerned with the regulation of social and daily life.

The religious belief taught in the Avesta rests on the dualism of the two great principles, *Ahura-Mazda* or "the good," and *Angrô-Mainyu*, or "the evil principle." The genii subordinate to the former are the *Amesha-s'pentas*, six of whom are named in the Yas'na, namely: Vohumanô, who protects living beings; Asha-vahista, or the genius of fire; Kshathra-vairya, or the genius of metals; S'penta-ârmaiti, or the (female) genius of earth; Haurvat', or the genius of water; and Ameretât', or the genius of trees. They are severally opposed by the *Daevas*, or demons, subordinate to Angrô-Mainyu,—by Akomanô, Andar, S'aurva, Nâonghaithi, Tauru, and Zairicha. Other demons occur in the tenth Fargard of the Vendidad. Both these principles—which in the more philosophical language of the second part of the Yas'na (the Gâthâs) are also conceived of as the principles of existence and non-existence, of life and death, of good and evil—pervade creation and are in permanent strife. The worshippers of fire belong to Ahura-Mazda, whereas the worshippers of the Daevas are possessed by Angrô-Mainyu, the spirit of evil.

It is the latter class of deities which throws a strong light on the obscure antiquity of the sacred books of Zoroaster. The Daevas are in substance and name the Devas of the Hindus. To the latter, however, they are the good and friendly gods, protectors of men, and worshipped by them in sacrificial acts. The religion of Zoroaster assumes, therefore, the character of being antagonistic to the Hindu creed; and, in accordance with this view, we find that Indra, one of the principal Vaidik gods, and one of the principal Hindu gods of the later literature, is in the Avesta the Daeva Andar; that the *Nâsatyas*, or As'wins of the Hindus, are the Daeva Naônghaithi; and S'arva, a later name of S'iva, is the Daeva S'aurva. It would seem, therefore, that Zoroaster belonged to a period of antiquity when great religious dissensions had already separated, or begun to separate, the two sister nations of the Hindus and Parsees; but it would be hazardous to extend this inference to any allegation of date, or even to the assumption that Zoroaster preceded the Vaidik songs of the R'igveda poetry; for though a belief has been recently expressed that the word *faradashti*, in a R'igveda hymn, is the Sanskrit form for the name Zarathustra, this bold conjecture is noways warranted, neither by a sound comparison of both words nor by the context in which faradashti occurs; whereas, on the contrary, there are circumstances which seem to indicate that Zoroaster inveighed against that form of Hindu worship which belongs to a period posterior to that of the R'igveda hymns. It is remarkable, for instance, that though there is a manifest tendency in the Avesta to invert the character of the friendly deities of the Hindus, the Zend *Ahura*, which emphatically occurs as a propitious name in Ahura-Mazda, corresponds in meaning and form with the word *Asura* of the R'igveda; whereas this same word *Asura* means a demon in the literature of the Hindus subsequent to the Vaidik poetry, and then only is the counterpart of the Avesta word.

The worship taught by Zoroaster seems to have been of the simplest kind, the adoration of fire by means of hymns and offerings, chiefly, if not exclusively, taken from the vegetable kingdom. An essential concomitant of the sacrifice is the juice of the Haoma, or the Soma plant, which occupies an important part also in the Vaidik rites. [VEDA.] This worship however must not be confounded with the complicated ritual of later periods of the Parsee creed, which assumed a similar development to that based by the Hindus on the R'igveda text, and is indicated by several portions of the Avesta, which cannot be looked upon as its earliest part.

This part evidently consists of the second division of the Yas'na, or the Gâthâs, for some of them are quoted several times in the remaining portions of the Avesta. But whether all the Gâthâs precede the first part of the Yas'na and the rest of the Avesta, and whether the dialect in which they are written differs from the language of the rest merely on account of local peculiarities, as Professor Westergaard holds, or on account of its earlier date, as other scholars assume, is a question which it would be difficult to decide in the present imperfect state of Zend philology. Nor would it be safe to say whether Zoroaster, to whom the original Avesta is ascribed, composed all or any of the remains in which the present collection has come down to us. Dr. Haug, it is true, who has given us a translation of the Gâthâs, says in a lecture he delivered at Poona, on the 1st of March, 1861: "I shall now give the proofs that these collections of ancient songs (the Gâthâs), or at least some of them, were really composed by Zarathustra himself, with some remarks which will throw light on the origin of the religion. 1. Whilst in those portions of the Zend-Avesta which are written in the usual Zend language (or it might perhaps more properly be called Bactrian) we find Zarathustra spoken of in the third person; now in these songs he is speaking in the first person, and sometimes calling himself by his own name, so says he in one passage (Yas'na, 43, 8): 'I am Zarathustra, I shall show myself as a destroyer to the wicked, and a comforter to the good.' 2. From the whole tenor of these songs (chiefly of the second collection, called Gâthâ-ustavaiti) we are led to the opinion that a man of quite an extraordinary stamp stands before us, acting a grand part, not only on the stage of his country's history, but on that of the universal history of the human race. He says that he is a prophet or a messenger, sent by God to propagate civilisation, especially agriculture and the blessings of a settled state of life (once he is called a prophet of the spirit of the earth, Geusurvâ), and to destroy idolatry as ruining the body as well as the soul." But it is clear that arguments of this kind do not warrant the certainty with which the inference is propounded that Zoroaster himself composed these songs, and that no later writer, according to the tradition he had received, could have indited the poetry which has called forth the foregoing remarks. Questions like these it seems premature to decide at a time when the grammatical laws of the language of the Avesta are not yet definitely known, when no real dictionary of this language is yet in existence, and when the few translators of the Avesta reproach each other, apparently not without good cause, with having misunderstood, or imperfectly understood, the most important parts of the sacred texts, either from clinging too much to tradition, which is not always safe, or from neglecting it altogether and inventing fanciful meanings of words. Those seriously engaged in the study of the old Parsee texts will not be misled by bold assertions of dates and confident interpretations of texts, but to the general reader it is wiser to confess that the time is not yet come to decide whether Zoroaster is the real author of all or any of the fragmentary portions of the Avesta which are the subject of this brief notice, nor to venture upon a guess at the period at which he may have founded the Parsee religion. All that is really settled by modern investigations is that it would be erroneous to assign to him the date of Darius' father, since it is indubitable that the Kavâ Vistas'pa of the Zend-Avesta, under whose reign Zoroaster lived, is not the Vistas'pa or Hystaspes, who is the father of the celebrated king Darius, the lineage of the latter being totally different to that of the former. When therefore the modern Parsees assign to their prophet the date of 550 B.C. they must be wrong; and if Zoroaster really lived at any of the remote dates which have been guessed by European writers, this fact would give us the interesting conclusion that there is a religious community which believes its founder to have existed about 1000 years later than he actually lived.

ZENITH and NADIR, two Arabic terms, imported into Europe with astronomy, to signify the point of the heavens immediately above the spectator, and the opposite (invisible) point below him. The latter term, though still mentioned in books on the use of the globes, is quite obsolete among astronomers; the former is very frequently employed.

The zenith is the point at which a vertical line cuts the heavens. If the earth were a sphere, this vertical line, or that in which a plumb-line hangs, would pass through the centre of the sphere. But the earth being a spheroid, the vertical line, which is everywhere perpendicular to the tangent-plane, does not pass through the centre of the spheroid, but a little nearer to the spectator's side of the equator.

ZENITH SECTOR. This instrument is, as its name implies, a *portion* of a divided circle, which is employed in measuring the *zenith* distances of stars. Picard, in his celebrated operation for determining the figure of the earth, first applied a short arc to a long telescope, thus obtaining at the same time great accuracy with portability. The instrument which he used for measuring the celestial arc between Malvoisine, Sourdon, and Amiens, is figured and described in his tract entitled 'Mesure de la Terre;'* the following is a copy of his plate and description. The instrument is of iron, strengthened with edge-bars, and covered with copper in the places required. The limb contains only about the twentieth part of the circumference of a circle of ten feet radius, and is divided by transversal lines [VERNIER] to thirds of a minute. The telescope is ten feet long, and the wires are illuminated either from the top or by an aperture on one side of the telescope. The plumb-line is enclosed in a tin tube to protect it from the wind, and the observations were always made in a close apartment through an aperture in the roof.

The figure shows all this sufficiently, and also the foot-screws for setting the axis vertical, which it is when, on turning the instrument round, the plumb-line hangs before the same division of the limb. In making the observation, suppose the axis to be vertical and the limb to be towards the reader, as in *fig.* 1 (the limb should also be in the plane of the meridian), and the telescope directed to a star, at its transit. Now if we suppose a line to be drawn through the centre, parallel to the line of sight of the telescope, the angle between the line so drawn and the plumb-line is the zenith distance of the star; but as the point where the arc is cut by the line supposed is not as yet defined, except by its parallelism to an optical and intangible line, there is as yet no measure. Read off, however, the division on which the plumb-line beats. Turn the instrument half round on its vertical axis, when the plumb-line remains on its former division, and the telescope points to the same zenith distance, but on the other side of the zenith; if, then, we would observe the same star as before, the sector must be turned on its horizontal axis through twice the zenith distance; and as the plumb-line always keeps parallel to its position, and passes through the centre, the division on which it now beats must be distant from the division first bisected by twice the angle moved through, that is, by twice the star's zenith distance, and the division which bisects the two readings is the zero point, or reading which corresponds to the zenith. It is not necessary that the star should be observed in both positions on the same night, provided the centre and arc of the sector continue to have the same position with regard to the line of sight. In this case, reversion on a following night will serve just as well for determining the division which corresponds to the zenith direction of the telescope. If this reading is not that which was intended by the maker, the difference is called the error of collimation, and is applied

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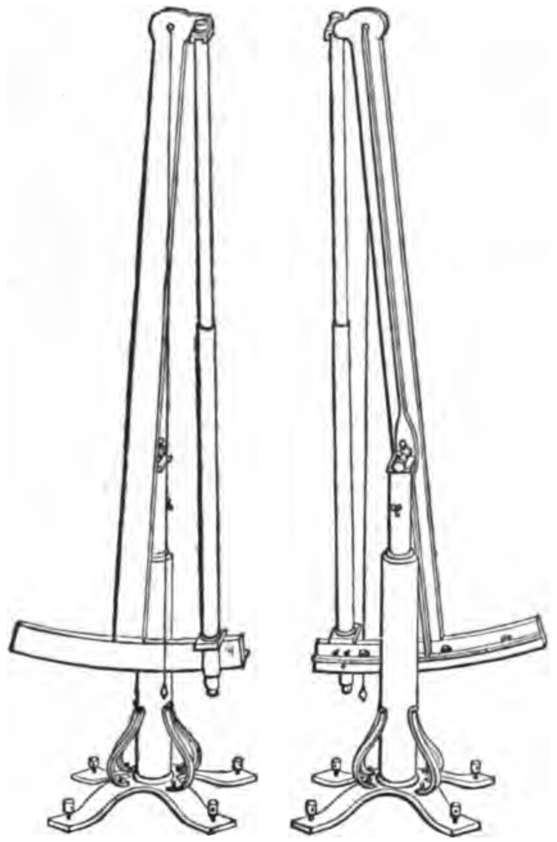
* The first edition of this admirable work was published in 1671; there have been numerous reprints of it since.



as a correction, additive or subtractive, to all the observations, according as they are on one or the other side of the zenith.

Picard enters into no details with respect to his observations, but gives at each place a zenith distance, which is the mean of a considerable number. He only observed one star, and that to the north, namely, the Knee of Cassiopeia (δ), giving as a reason, "that a star nearer to the zenith would have been more difficult to observe, and that if the star had been between the two zeniths, the error of the instrument (the division corresponding to the zenith, or error of collimation), which might have been imperfectly determined, would have been doubled in the apparent distance between the two zeniths, because then the sum of the two observations must have been taken; whereas when a star is always observed on the same side of the zenith, there is only the difference to be taken, which must be correct, provided the instrument is well centred and well divided."[*]

In 1674 Hooke published 'An Attempt to prove the Motion of the Earth from Observations,' in which he describes the instrument he contrived for observing the distance of γ Draconis from the zenith of Gresham College, and the apparatus for measuring the variations which might occur. This consisted of an object-glass of 35 feet focus length, fixed at the top of the house, and referred by two plumb-lines hanging from a bar in the object-cell and passing through apertures in the floors, to a system of wires below. Before each observation Hooke set certain marks in his wire-cell to the plumb-lines, then fixed the wire-cell, removed the plumb-lines, and bisected the star; after the observation, he verified the position of the wire-cell on replacing the plumb-lines. There is a great deal to admire in this simple and ingenious contrivance, but his *mensurator* for noting the small variations seems clumsy and inexact. "Inconvenient weather and great indisposition in his health" limited Hooke's observations to four in number, from which he erroneously concluded that there was an annual parallax of the earth's orbit, and therefore that Copernicus's theory was true. With very little alteration, such as a nicer reference of the plumb-lines to the cell of the eye-piece, and a screw micrometer for a mensurator, Hooke's apparatus would still be applicable; and if his idea of using a deep dry well for the telescope-tube were adopted, we conceive that most accurate determinations might now be made.

Several observers about this time discovered a motion in the stars which they could not account for. Picard, Roemer, and Flamsteed all found that the position of Polaris varied at different times of the year, and Flamsteed fancied that the change was due to parallax. In or about 1725, a gentleman of the name of Molyneux, then resident at Kew, employed Graham to make him a *parallactic* telescope, so called from its object, namely, to discover the change of place in the stars occasioned by the earth's change of position in her orbit. This is described in Smith's 'Optics,' book iv., cap. 7, and more fully in Mr. Molyneux's own words in Bradley's 'Miscellaneous Works and Correspondence,' p. 93. It consisted of a telescope 25 feet long, with a short cross axis at the upper end, just at the place of the object-glass. This axis was so adjusted on its supports that the telescope moved in the meridian. A plumb-line hung on one end of the axis and passed over a dot in a plate fixed on the tube near the eye-end. The telescope was drawn forwards in the meridian by a string and weight passing over a fixed pulley, and pushed back by an antagonist-screw, which had a divided head and index. To make the observation, the plumb-line is first made to bisect the dot by the screw, and the division read off; then the star is bisected also by moving the screw, when the division is again read off. The revolutions and parts through which the screw is moved measures the angular distance of the star from a line in the heavens, which continues fixed, if there is no change in the relation of the object-glass and wires to the axis and dot.

Observations were made at Kew for some time with this instrument by Molyneux, Graham, and Bradley; and in 1727 Bradley had a zenith-sector constructed by Graham with which he made his celebrated discoveries of aberration and nutation. There is a short description of this instrument by Maskelyne in the first volume of his 'Greenwich Observations,' p. 9, which Rigaud has reprinted, with some memoranda by Bradley, in the 'Miscellaneous Works,' &c.; but Bradley himself gave no description in his Memoir on Aberration ('Phil. Trans.' vol. xxxv., p. 637), and in his following Memoir on Nutation ('Phil. Trans.', vol. xlv., p. 1) satisfied himself by referring to the description of a sector on a similar construction. ('Dégré du Méridien entre Paris et Amiens,' 1740.) This last-mentioned sector was made by Graham for the measurement of the degree in Lapland, and afterwards employed in the remeasurement of Picard's arc. We have now a full and minute description of Bradley's instrument, with numerous plates, in a work entitled 'Operations for the Verification and Extension of the Abbé de la Caille's Arc of the Meridian,' by Thomas Maclear, Esq., pp. 67-81, published by order of the Lords of the Admiralty. This account is by the astronomer-royal, who directed the alterations required to fit the sector for the field. The principal parts of this instrument, as originally made by Graham, are a telescope with a short sector attached to the eye-end, and a short cross or transit-axis to the object-end, which causes it to move in the meridian when properly adjusted. A plumb-line passes over a fine dot at the extremity of the upper axis, and beats on the divided sector below, that is, it almost touches the dot above and arc below, but still hangs perfectly free. To prevent any disturbance from the wind, the plumb-line is screened by a tube, and the bob hangs in water that it may sooner come to rest. To make the telescope describe the meridian correctly, as well as to get a proper fixing for the clamp and micrometer-screw, another arc is fixed to the wall, and the telescope carries a frame with rollers at its eye-end, and is thus kept in contact with the fixed arc before and behind. A clamping apparatus, which slides along the fixed arc, and can be attached to it by screws in any position, carries a fine screw with a micrometer head, which pushes the telescope by acting on a piece of hardened steel, while the telescope resists either by gravity or by a counterpoise weight. There are numerous parts and contrivances for different adjustments, which will be easily understood from Mr. Airy's account. In making the observation, the telescope is first to be set, or nearly so, to the star, the bisection of the upper dot is verified, and then a division below is bisected by carrying the screw one way, *forward*, for instance, and the micrometer head is to be read off. When the star is in the centre of the field, it is bisected by carrying the screw still *forward*, and the micrometer is again read off. Finally, the screw is still to be carried *forward* till the next division is bisected, and the micrometer read off. A simple proportion will give the quantity, which is to be added to the first reading, or subtracted from the second reading, in order to get the reading corresponding to the star.[*] Bradley's sector as originally made was not reversible, and was therefore only fit for measuring differences or variations. When, after its removal to Greenwich, actual zenith distances were required, the instrument was shifted across the room, from the east to the west side, where a second fixed arc, &c. were ready to receive it. We need not say that this was very objectionable, as such an operation, take what care you may, is always liable to derange the relation of the parts of the instrument, and so to lead to untrue conclusions. Even while it was at Wanstead, and considered to be immoveable, a slight change seems to have taken place, which has been investigated by Dr. Busch, in the 'Reduction of the Observations made by Bradley at Kew and Wanstead,' Oxford, 1832. In remounting it, the astronomer-royal has given the property of reversion very satisfactorily, and Mr. Maclear's observations with it are of extraordinary accuracy.

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[*] We have given the above extract from Picard because it shows, we think, that he did not reverse his sector at each place; if he had, he must have got a double zenith distance free from all *fixed* errors but those of centre and division, and his reasoning is not correct. The assumption which he tacitly makes, that the error of collimation continued to be the same during his observations at *different* places, is not allowable. It is evident that with such an instrument the exact adjustment to the meridian would be difficult, and hence probably his choice of a star, which, being distant from the zenith, required less nicety in this adjustment.

[*] In some of the books referred to, it will be seen that the dot bisected before observing the star is directed to be bisected again, and the *mean* of the readings taken. But a screw which carries weight never reads the same when moved forwards and backwards, and it is always safest to carry the screw the same way in the same operation.

A sector was used in the measurement of the meridian in France, by Cassini de Thury and La Caille, which greatly resembled the sector of Picard, except that the arc was of much greater extent, being 52½° and framed with three radii. The telescope was fixed at the back of the instrument, so as to be at once more firmly fastened and out of the way of the plumb-line; and, lastly its micrometer-screw was applied to the wires of the telescope (sometimes called the *interior* micrometer), instead of moving the whole sector. In this mode of observing, the instrument is set approximately to the star, and the nearest dot accurately bisected. When the star is in the centre of the field, it is bisected by the micrometer-screw which carries a wire in the focus of the object-glass, and thus the excess or defect from the nearest dot is ascertained. This improvement in the application of the micrometer-screw is due to the Chevalier Louville, and in this respect we prefer the French to the English construction. See 'La Méridienne de l'Observatoire Royal de Paris verifiée,' par M. Cassini de Thury, Paris, 1740. The sector is figured at page 31, and described at page lxxi.

Bouguer and La Condamine, in their measure of the arc of Peru, were compelled to fabricate their own zenith sectors, and adopted a very elegant mode of graduation, the merit of which is given by La Condamine to their colleague Godin. The telescope and arc being prepared, a star is selected which has pretty nearly the same zenith distance at both extremities of the arc of the meridian. Now calculate approximately the value of the chord of the double zenith distance of the star, and find what fractional part it is of the radius. Suppose it is nearly $\frac{1}{17}$ of the radius, then take a beam compass, mark two dots on the arc, and step seventeen times with the same opening along the radius, and so fix the dot over which the plumb-line is to pass. The instrument is now graduated, and is used as follows:—After being adjusted to the meridian, the plumb-line is made to pass over the upper dot and one of the lower dots, after which the star is bisected by the interior or Louville's micrometer. On a following day the instrument is reversed, and the plumb-line being brought over the upper dot and the other lower dot, the star is again bisected by the micrometer. It is plain that the double zenith distance of the star, corrected for refraction, aberration, &c., is measured by the arc subtended at the central dot by the two dots below ± the sum or difference of the micrometer readings. But the arc is, by construction, that the sine of which is $\frac{1}{34}$, which is found from the tables; and the value of the micrometer readings being also known, the zenith distance of the star is known. The operation may be repeated at the other end of the arc with the same star, and using a different submultiple of the radius. See 'Mesure des trois premiers degrés du méridien,' par M. de La Condamine, Paris, 1751, pp. 105 et seq.; 'Figure de la Terre,' par M. Bouguer, Paris, 1749, pp. 176 et seq.

We insert here the method employed by Maupertuis, La Caille, and others to ascertain the value of the total arc of the sector. A line of considerable length was carefully measured from a well-defined spot and a signal erected; then a perpendicular was measured from the signal, of such a length as very nearly subtended at the spot the arc to be verified, and here a second signal was placed. The sector was then laid horizontally on a bed prepared for it, the centre being exactly over the defined spot, and the telescope pointed to the first signal; when this was done satisfactorily, a fine line was stretched over the centre and the first dot of the divided arc. Now shifting the sector round, the second signal was bisected, and it was seen what division was bisected by the line which continued to pass over the centre. The true angle is evidently that marked on the ground, and is calculated from the given length of the perpendicular and the distance. The value of the arc read off on the sector is compared with this, and the error of the total arc detected, which is afterwards used for correcting all the angles observed. At present the value of the total arc of a sector would be determined by a comparison with the mural circle.

In 1775 Bird erected a zenith sector at the Observatory of Oxford, which is in most respects similar to Graham's, but it is fixed to an upright pillar which revolves freely, so that the instrument is reversible. From some cause or other, though observations have been made with this instrument, they have not been considered satisfactory. It appears to us to be an excellent instrument, and one capable of doing good work, though one chief use of zenith sectors, namely, ascertaining the index error of the meridian declination instrument, has been supplied to modern circles by observations by reflexion.

The zenith sector of Ramsden, which was used in the trigonometrical survey of Great Britain, and in the Holstein arc, is described and figured in great detail in the 'Phil. Trans.' for 1803, and in the second volume of the 'Account of the Ordnance Trigonometrical Survey of England and Wales.' It was burned in the fire which consumed a considerable part of the Tower in 1841. As this instrument is very fully detailed in the account referred to, it is useless to enter into particulars here. Ramsden viewed the upper dot by a long microscope, which saved considerable trouble, as well as avoided the chance of deranging the bisection by mounting to read it. The 'Astronomical Observations with Ramsden's Zenith Sector,' reduced by Lieutenant Yolland, R.E., were published in 1842 by order of the Board of Ordnance.

After the destruction of Ramsden's sector, Colonel Colby applied to the Astronomer Royal for his advice as to the best form of instrument for determining latitude *in the field*. The construction given by Mr. Airy, and executed by Mr. Simms, differs in many respects from any which preceded it. The description, with explanatory figures, is to be found in the 'Monthly Notices of the Royal Astronomical Society,' vol. v., p. 188. The vertical axis, which is cast in one piece, and strongly framed, carries at its back three levels, one above the other, which being read off at the moment the star is bisected, determine the position of the axis with respect to the zenith. The telescope-frame with the eye- and object-end is cast in another solidly braced piece, and is held at its middle on a centre in front of the vertical axis. This second frame moves freely for a few degrees on each side the zenith. The divided arcs are graduated on the vertical axis near its top and bottom, and there are four micrometer microscopes, one at each side of the object and eye-end, the tubes of which are bored in the solid telescope-frame. There is a wire-micrometer in the focus of the telescope. A stop to the axis enables the observer to turn the instrument exactly half round by touch, and almost instantaneously. The observations are made thus:—The instrument being pretty nearly in the meridian, and the axis vertical, the telescope is set nearly for the star, and the microscopes are read off. Before the star reaches the centre of the field, the observer bisects it with the micrometer-wire, noting the time, while the assistant reads off both ends of each level. The whole instrument is then turned half round, and the star is again observed, the bisection being now performed by the tangent-screw of the telescope-frame, the time is again noted, the assistant reads off the levels as before, and, finally, the arcs above and below are read off by the micrometer microscopes. In this way the double zenith distance of a star, free from all error of collimation or of the vertical axis, may be obtained in a few minutes. This instrument performs very satisfactorily. The telescope is one of 3½ feet focal length, and the instrument bears the same relation to a mural circle that the ordinary sector does to a quadrant.

When Troughton first proposed the mural circle as the best form for a meridian declination instrument, great doubt was thrown on the practicability of observing by reflexion with sufficient nicety, and in that case, as the mural circle does not reverse, a supplementary instrument was wanted to show the position of the zenith or horizon. Partly on this account, but chiefly to settle the constants of aberration and precession with the greatest precision, Troughton planned a *zenith tube*, consisting of a telescope of 25 feet focal length, without any sector, and in which the variations of zenith distance of γ Draconis and close zenithal stars were to be measured by a micrometer-screw. The telescope rests on its lower end, continued beyond the focus, on a piece which has adjustments for verticality, and a collar below the object-glass is pressed by a spring into a Y bearing. The wires at the focus are moved by a micrometer-screw, and the star and wires are seen through a diagonal four-glass eye-piece. The plumb-line hangs within the tube, and is viewed above and below by micrometer microscopes. Instead of adjusting the plumb-line before each observation, it is bisected by the micrometers after the observation, and a correction applied which is deduced from the upper and lower readings. Mr. Airy having had some reason to suspect that the wire twisted on reversing the instrument, gave a double suspension to the plumb-line, and made the instrument reversible on a star in the same night, by using a stop as in the ordnance sector. The observations with the zenith tube are printed yearly in the Greenwich Observations.

The zenith sector has not been much used upon the continent since the great surveys made in the middle of last century for ascertaining the figure of the earth. In the French arc from Dunkirk to Formentera, the latitudes were observed by the repeating circle, and in some of the stations there is reason to suspect that error has been committed. More recently, the transit in the prime vertical has been employed in Germany and Russia for ascertaining differences of latitude, and as it would seem with great success. [TRANSIT.] A prime vertical transit was constructed by Repsold for the imperial observatory of Pulkowa, of which a most favourable account has been given by Professor Struve. While admitting the excellence of this kind of instrument for telescopes of moderate size, we do not see how they can equal, far less surpass, the zenith sector when made reversible and of the proper magnitude.

Some years ago Mr. Babbage proposed a construction for a zenith sector ('Memoirs of the Astronomical Society,' vol. ii., p. 101) which might perhaps be applied in the following manner:—Conceive a parallel ruler to be placed upright, one of the bars being made into a vertical axis with the necessary adjustments, and the other carrying a telescope. It is clear that if the bands were equal the telescope would continue parallel to itself whether the ruler be open or shut. But if one of the bands is a little longer than the other, then a very large angular motion of the band will give a small angular motion to the telescope-bar, and as the measurement of the former angle can be easily made with tolerable accuracy, the latter angle can be computed with great exactness.* Exquisite workmanship would no doubt be required to make such an instrument answer, but we think that for this and other differential purposes Mr. Babbage's suggestion is deserving of attention, especially where telescopes of limited size are used.

The adjustments of a zenith sector or zenith tube will differ according to the construction of the instrument. Where it is not reversible, the time of the transit of a star near the zenith must be got from observations with another instrument, and the star *made* to pass the meridian-wire at the calculated time by the proper adjusting screws. When this is done and the telescope secured, a star must be made to pass along the declination-wire (this should be carried by a micrometer-screw) by twisting the wire-cell, when the adjustment for a fixed zenith telescope is complete. If the telescope rest on a cross axis and carries a sector, the cross axis must be made horizontal, the transits of stars towards the extremities of the arc must be observed, and the azimuthal deviation ascertained [Transit] and corrected; or, the time at which an extreme star *should* pass being known, the cross axis at top and fixed arc below must be turned so as to *make* the star pass at the right time.

When the instrument is reversible, the axis is first to be set truly upright. Suppose the instrument in its meridian position nearly, and face east, read off the division bisected by the plumb-line, or the two ends of each level. Now turn half round, read off again, and bring, by the adjusting screws, the plumb-line or the levels half-way to the first readings, and finally adjust each level by its own screw to read each end alike. If this be carefully done, when the instrument is restored to its first position, the plumb-line or levels will remain undisturbed by the last reversal. Now turn the axis one-quarter round, and correct whatever change is thereby caused, by the east and west screws of the axis. The axis is now vertical, or by a repetition of the process may be made so. The next adjustment is to make the line of sight describe a great circle. This is the collimation error of the transit. This may be done as described above, from knowing the true time; or by observing one star or two stars near the zenith in *reversed* positions, when the disagreement between the observed and computed difference will give the quantity and direction of the alteration required. In a modern instrument this adjustment would be by antagonist screws carrying the wire-plate. If the instrument be simply a zenith-tube, make a star run along the declination-wire, and the adjustment is finished. With a sector place the instrument nearly in the meridian, observe the transit of a zenith star, which gives the time. Then by turning round the axis, make an extreme star pass at the proper time and clamp the axis. In the present ordnance sector the instrument rests on a tray which is adjusted as to meridian by strong screws on the stand, acting against the sides of the tray. Finally, twist the wire-cell till a star runs along the declination-wire. A comparison of the zenith distances of the same stars observed in reversed positions of the instrument, will give the error of collimation, and this *may* be corrected if the observer wishes, but it is better to leave it untouched, and to consider the sum of two observations, Face East and Face West, as a double zenith distance.

(For plates and descriptions of some of the constructions here referred to, and others which we have omitted, see Pearson's *Practical Astronomy*, vol. ii., pp. 531, 554, plates xii., xiii., xxvi., xxvii.)

ZENZO, ZENZIC. The Arabs used a word for the square of a number which has the same meaning as the Latin word *census*; accordingly Leonard of Pisa, Lucas Pacioli, and the early Italians, used *radix* and *cosa* for the unknown quantity, and *census* for its square, which became *censo* in Italian. The Germans corrupted these into zensus and zenso, and hence in their algebraic writings, and in some of the early English ones, the zenzic power is the square. From this and the word cube, various denominations of powers were formed, as zenzi-cubic for sixth, zenzizenzizenzic for eighth, &c., from which we are now happily delivered.

ZERO. [Thermometer.]

ZERO. [Infinite, &c.]

ZETETICS, a name given by Vieta [Biog. Div.] to the part of algebra which consists in the direct search after unknown quantities: it is now disused.

ZEUS, the supreme deity of the Greek Olympus, the god of heaven and of earth, to whom the Jupiter of the Romans nearly corresponds both in power and attributes, was probably originally an elemental divinity, who was worshipped as the god of rain, snow, lightning, &c. Apart from other considerations the etymology of his name, both in Greek and Latin, would seem to lead to this conclusion.

According to Homer, Zeus was the son of Kronos and Rhea. [Kronos.] In order to save her son from being destroyed by his father, Rhea concealed him soon after his birth in a cave in Crete, where he passed the first years of his life. As Zeus grew up, Kronos called to his aid the Titans, in order to secure his dominions against his son; but they were eventually conquered, and Kronos himself dethroned by the youthful Zeus. In the Homeric poems Zeus is represented as the supreme ruler of the gods and of men; and though subject himself to the decrees of Fate, his commands cannot be disobeyed; his wisdom is infinite, and his power irresistible. His wife was Hera, and their children Hephæstus, Ares, and Hebe. The worship of Zeus was co-extensive with the Grecian race. His temples were numerous, the chief being at Elis and at Athens—the former contained Phidias's sublime chryselephantine statue of the god, the latter being, when perfect, the noblest temple perhaps of the ancient world.

Cicero informs us ('De Nat. Deor.,' iii. 21) that there were three Roman deities of the name of Jupiter: one the son of Æther; the second, the son of Heaven; and the third, the son of Saturn. The last was worshipped at Rome under various names, and many temples were erected to his honour, of which the most celebrated was the one on the Capitoline Hill, where he was worshipped under the name of Jupiter Optimus Maximus.

As the supreme god, Zeus taxed the highest powers of the artists of ancient Greece. The Greeks themselves believed that Phidias, in the seated chryselephantine statue of Zeus which he executed for the temple of Elis, had attained the loftiest conception of the divinity. Zeus himself, Pausanias tells us (b. v. c. 10), gave a visible expression of his approval of the sculptor's art; and Quinctilian declares that the work equalled in majesty the god himself, and added somewhat to the religion of those who saw it. The statue has long been lost, but several attempts have been made to restore it from contemporary descriptions—the best known being that of M. Quatremère de Quincy, in his 'Jupiter Olympine.' This work of Phidias seems to have been accepted by the Greeks as an authoritative model for the form and features of the deity. Phidias probably followed in the general conception some more ancient type, but his was thenceforward the normal form which all succeeding artists, according to their ability, sought to reproduce. Müller thus characterises the external features of Zeus, as found in works of the best and later periods of Greek art:—"The hair rose up from the centre of the forehead, like that of a lion, and then fell down on both sides like a mane; the brow clear and bright above, but greatly arching forward beneath; eyes deeply sunk, but wide open and rounded; delicate mild lineaments round the upper lip and cheeks; the full rich beard descending in large wavy tresses; a noble, ample, and open chest, as well as a powerful, but not unduly enlarged muscular development of the whole body." ('Ancient Art,' § 349.) From this general character, which belongs to the best statues of Zeus, deviations occur, where he is represented in a youthful form, or as an excited and vengeful deity.

Zeus was usually represented seated on an ivory throne, with a sceptre in his left hand and in his right a thunderbolt. The Olympian Zeus of Phidias bore in his right hand a Victory, made like the statue itself, of gold and ivory. In early art the representations of Zeus chiefly have reference to his divine character, and his more sublime attributes. Later, and especially as art became the minister of luxury, and too often of voluptuousness, the intrigues of the god with the lesser goddesses, and with mortals, afforded a more acceptable class of subjects, and Jupiter and Io, Jupiter and Ganymede, Leda and the like, were figured in every variety of form and material; and at the revival of the study and imitation of classical art, it need hardly be added that this series of circumstances in the mythic history of Jupiter was seized upon with avidity by the painters and sculptors of Italy.

ZIF. This name, written זִו in Hebrew, occurs only in the first book of Kings, in the 6th chapter, and in the 1st and 37th verses. It is the month now called Jyar. The word is derived by the Jews from a root signifying to be splendid, in reference to the splendour of the season when the month occurs, April and May. The word is found several times with a slight orthographical difference in the book of Daniel, and is usually translated "brightness." [Bul.]

ZINC (Zn). *Spelter*. A commercial metal which has been known in the metallic state since the time of Paracelsus. It is never met with in the native state, but is extracted from two ores—*calamine*, or carbonate of zinc, and *blende*, or sulphide of zinc. A native oxide of zinc found in New Jersey has also recently been rendered available for the extraction of the metal.

The commercial metal is never pure, though usually sufficiently so for most chemical purposes. The pure metal may be obtained by dissolving common zinc in dilute sulphuric acid, filtering, treating with excess of sulphuretted hydrogen, again filtering, and precipitating the boiled filtrate with carbonate of soda. The washed and ignited carbonate must then be distilled in a porcelain retort with charcoal from lump sugar.

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* Let the length of the upper band be a, of the lower band $a+h$, the distance between the bands b, and let the bands be horizontal; the telescope-bar makes with the zenith an angle the tangent of which $= \frac{h}{b}$; when the bands are inclined at an angle θ, the tangent of zenith distance $= \frac{h \times \cos\theta}{b}$. The quantity h may be measured and regulated by a micrometer-screw and such a tilt given to the telescope, that the star can be observed in reversed positions of the axis, and thus the double zenith distance found. The zero of the micrometer-screw is found from its position, when opening and closing the bars makes no change in the place of a star. We prefer this construction of a zenith sector to that of Mr. Babbage. The zenith point is only to be got by reversion, and the upright bar must be watched and ascertained by levels, &c. Mr. Babbage has given an exact formula, when the points of attachment of the telescope-bar are constant. We have supposed an adjustment in one of these points, which allows the bands to be horizontal, while the telescope-bar is inclined.

Zinc is a bluish-white crystalline and hard metal, brittle at 400° Fahr., malleable and ductile between 300° and 200°, but again somewhat brittle at ordinary temperatures. It melts at 773°, and boils at a bright red heat estimated by Deville at 1904°. In contact with air the vapour burns with a magnificent greenish-blue flame, forming copious white flocculi of protoxide. At ordinary temperatures zinc gradually oxidises in a moist atmosphere, but the superficial film of oxide preserves the remaining metal for a long time unchanged. It readily dissolves in dilute mineral acids, and in concentrated solutions of potash and soda. It also combines with chlorine, iodine, and bromine at ordinary temperatures. The equivalent of zinc is 32·7, and its specific gravity 6·8 to 7·1.

The following are the principal compounds of zinc :—

Oxide or Protoxide of Zinc (ZnO), *Zinc-white.*—This is the oxide which exists in the native carbonate. It may be prepared in various modes : first, by merely igniting the metal in contact with air; in this case combustion takes place readily, and a light white compound is formed, which was called by the old chemists by the various names of *nihil album, lana philosophica, pomptolix,* and *flowers of zinc.*

Oxide of zinc may also be procured by dissolving the metal in a dilute acid, either the sulphuric, nitric, or hydrochloric, and decomposing the solution by a carbonated fixed alkali; carbonate of zinc is first precipitated, but this, when heated, loses its carbonic acid, and the oxide is obtained as a yellowish powder.

In the manufacture of brass an impure oxide of zinc condenses in the flues of the furnaces and is sold under the name of *tutty.*

The properties of oxide of zinc are,—that it is inodorous, insipid, insoluble in water, and infusible by heat; it combines readily with acids, and also with the alkalies ammonia, potash, and soda. So that when it is precipitated by them, they redissolve it if added in excess. It is the basis of all the oxisalts of zinc.

Peroxide of Zinc, probably a binoxide (ZnO_2 ?), is obtained by taking gelatinous hydrate of zinc, and pouring upon it an aqueous solution of binoxide of hydrogen (oxygenated water), containing about eight times its volume of oxygen gas, and shaking the mixture thoroughly; the peroxide of zinc resulting from this operation is white, inodorous, insipid, and decomposes spontaneously when kept moist or when heated. It is also decomposed by acids, which dissolve protoxide of zinc and reproduce binoxide of hydrogen.

Chloride of Zinc (ZnCl) may be formed by the direct action and combination of these elements. When zinc filings are thrown into chlorine gas, heat and light are evolved, owing to their combination; it is more readily prepared by dissolving oxide, or still better metallic zinc, in hydrochloric acid, and evaporating to dryness; or by heating the metal in a tube through which dry hydrochloric acid gas is transmitted.

The properties of chloride of zinc are,—that it is colourless, has a very styptic taste, is readily soluble in water, and crystallises from it with difficulty; it is very volatile at a red heat. It was formerly called *butter of zinc.*

Bromide of Zinc (ZnBr) is formed by passing bromine in vapour over zinc heated to redness; or it may be obtained in solution by agitating a mixture of these elements and water: the solution is colourless, and when evaporated till a pellicle is formed, it becomes a crystalline mass on cooling.

This bromide has a sweetish, astringent taste, and is very deliquescent; it becomes dry when heated, and fuses at a red heat.

Iodide of Zinc (ZnI) is readily obtained by heating iodine and zinc together in water; the solution, when perfect, is colourless, and is to be evaporated in a retort, and when the water is entirely separated, the iodide of zinc fuses and volatilises in fine prismatic crystals. By exposure to the air this iodide is decomposed, the metal being oxidised, and the iodine set free.

Sulphide of Zinc (ZnS).—This compound, which exists plentifully in nature, is obtained artificially with considerable difficulty, and by the direct action of its elements is perhaps scarcely possible; but when oxide of zinc is heated with sulphur in excess, a yellow brown sulphuret of the metal is obtained; when also sulphuret of potassium is added to a solution of a salt of zinc, a white hydrate of the sulphide of zinc is precipitated.

Phosphide of Zinc is procured by strongly heating in a retort a mixture of six parts of oxide of zinc, six parts of phosphoric acid, and one part of powdered charcoal; a sublimed mass is obtained, which is of a silvery-white colour, metallic lustre, and vitreous fracture. Its composition has not been determined.

Selenide of Zinc.—If the vapour of selenium be passed over zinc heated to redness, the mass takes fire and explodes, and the exterior of the vessel is covered with a lemon-yellow powdery substance, which is selenide of zinc; this is partially soluble in nitric acid with the evolution of nitric oxide; and a red powder is deposited, which is however finally dissolved.

We shall now briefly describe some of the oxisalts of zinc, or those consisting of acids combined with oxide of zinc.

Nitrate of Zinc ($ZnONO_5 + 6HO$).—This salt is readily obtained by the action of the acid upon the oxide of the metal, or upon the metal itself; in the latter case nitric or nitrous oxide is produced according to the degree of concentration of the acid.

The solution of nitrate of zinc is colourless, and by due evaporation it yields colourless crystals, which are deliquescent; very soluble in water and in alcohol: they are decomposed by ignited charcoal, and impart to it a greenish-blue flame.

Sulphate of Zinc ($ZnOSO_3 + 7HO$).—This, which is the salt of zinc most extensively employed both in medicine and the arts, may be prepared by dissolving the oxide of the metal in dilute sulphuric acid; but it is always procured by acting on the metal itself, which is oxidised by the decomposition of water, with the oxygen of which it combines and evolves the hydrogen. The solution is colourless, and by evaporation readily yields crystals, which are usually small, and the primary form of which is a right rhombic prism. Sulphate of zinc has a disagreeable metallic taste; it is not altered by exposure to the air, but if moderately heated loses its water of crystallisation, and when subjected to a high temperature is entirely decomposed, the acid being expelled, the oxide only remaining. This salt is very soluble in water at 60°, and much more so in boiling water. There is an impure sulphate of zinc used in the arts, under the name of *white vitriol;* it is a colourless granular mass, obtained by the oxidisement of the native sulphide of zinc or blende.

Carbonate of Zinc ($2\,ZnOCO_2 + 3\,ZnO\,HO$).—Metallic zinc and hydrated oxide of zinc are both dissolved by an aqueous solution of carbonic acid; but the nature of the carbonate formed, when the excess of carbonic acid is expelled by spontaneous evaporation, has not been ascertained. When an alkaline carbonate is added to a solution of a salt of zinc, a white precipitate is obtained, which is the above compound of carbonate and hydrate of zinc, and not a simple carbonate.

Acetate of Zinc ($ZnOC_4H_3O_3 + 3HO$) is prepared by dissolving either the metal or its oxide in the acid, or by decomposing sulphate of zinc by acetate of lead. The solution is colourless, and yields thin rhombic plates, which are not deliquescent, but are very soluble in water. It is occasionally employed in medicine.

Characters of the Salts of Zinc.—They are usually soluble in water, colourless, have an unpleasant metallic taste; the alkalies ammonia, potash, and soda decompose them, precipitating a colourless hydrate, which is soluble in excess of these precipitants. The alkaline carbonates also decompose the salts of zinc, but the carbonate of ammonia only, when added in excess, redissolves the carbonate thrown down in any notable quantity. Hydrosulphuric acid decomposes neutral, but not acid or alkaline solutions of zinc; the precipitate obtained is a hydrated sulphide of zinc. Tincture of galls gives no precipitate, and ferrocyanide of potassium a white one with the salts of zinc.

Alloys of Zinc.—Potassium and sodium form with zinc brittle alloys, decomposable by exposure to air and moisture. With copper it combines to form brass, and with iron it yields a very hard alloy, which is very energetically acted upon by sulphuric acid. If plates of hot iron be dipped into melted zinc, they acquire the appearance of tin-plate, and the iron is prevented from rusting. Such coated iron is termed *galvanised iron.*

Sheet-zinc is now largely employed for covering buildings. Plates of this metal are also used in the construction of voltaic batteries.

ZINC, *Medical Properties of.*—In the purely metallic state, zinc produces no effect on the human system, but its combination with oxygen, forming oxide or flowers of zinc, is sufficient to invest it with considerable power over various organs, both those with which it comes into direct contact and some remote ones, especially the nervous centres. Its local action is that of an irritant, astringent, and desiccative, while its remote action is that of a tonic and antispasmodic. The emetic properties of the oxide are less than those of the sulphate or acetate, unless it meets with acids in the stomach. In this way it is rarely employed. It is for its remote effects that oxide of zinc is valued. While it has the properties common to all the metallic antispasmodics, it is distinguished by its power of restraining inordinate action of the nervous system; being calming and soothing. The brain and the function of sensation appear to feel less of its influence than the spinal cord. Hence the nerves of motion, and the functions of the circulation and respiration, are chiefly acted upon; it produces its effects speedily, but they quickly disappear when given in such doses as can be safely administered. The long-continued use of it seems to produce a dryness and induration of the frame, which, if carried to excess, is dangerous, but the lesser degree of which is in all probability the source of the utility of this medicine, by diminishing the mobility of the system; irregularities in the circulation, and sudden congestions of blood, being the immediate causes of attacks of epilepsy and hysteria, the diseases which are most benefited by oxide of zinc. This desiccating property renders it the most potent means yet discovered of checking the colliquative perspirations of consumptive persons. (See 'Clinical Lectures on Pulmonary Consumption,' by Theophilus Thompson, M.D., p. 194.) For use in this way, and even for use as an ointment, it requires to be prepared in a state of far greater purity than it is met with when prepared for use in the arts. Above all, it must be free from admixture with sulphate of zinc.

In spasmodic affections of the chest, such as asthma, angina pectoris, and palpitation of the chest, when these do not proceed from organic derangements, oxide of zinc is often serviceable, especially when combined with conium. In the cramps of the stomach to which habitual drunkards are subject, it is very useful.

Impure oxide of zinc is called tutty. It is sometimes used externally as a dusting powder, as a mild absorbent, on excoriations, and to heal chaps and cracks in the skin. It is also used as an ointment. Pure oxide of zinc forms an ointment of much value where a mild astringent is needed, especially in the chronic inflammation of the eyelids.

Carbonate of zinc when impure is termed calamine. This, after being subjected to divers processes, is called *prepared* calamine. The only use made of it is to form an ointment, which is most useful as an application to burns, excoriations, and superficial ulcers.

Sulphate of zinc is in small doses a very valuable astringent, tonic, and antispasmodic; in larger doses it is a very certain and speedily acting emetic; and in very large doses it is poisonous. It is the most useful emetic in cases of narcotic poisoning, as it is not so apt to inflame the stomach as tartarised antimony: but the stomach-pump is preferable to either.

The tonic effects are best seen in affections of the mucous membranes. In the suffocative catarrh of aged persons, and the extreme defluxions on the chest after influenza, sulphate of zinc affords a valuable remedy: it must be given in small doses, as the sudden suppression of the secretion may cause inflammation. Its utility is increased by combining it with the compound rhubarb pill, or with myrrh only. The use of the solution as an injection requires the same caution.

Acetate of zinc is possessed of nearly similar properties, but in a weaker degree; and as an injection, seems in some cases entitled to a preference.

Chloride of zinc, called also butter of zinc, is a powerful escharotic or caustic; this action results from its strong affinity for albumen and gelatine, which principles it abstracts from the living tissues, and so forms an eschar. Its powers in this way have been taken advantage of to destroy parts affected with malignant diseases, such as cancer and lupus, and to remove nævi materni, or mother-marks. In none of these is it to be resorted to unless they are very superficial. Deep-seated cancer of glands can scarcely be removed by it, but other forms are often successfully treated by it. (Walshe, 'On Cancer,' p. 219.) Properly diluted, chloride of zinc is most beneficially used to correct the fœtor from suppurating ears of children.

Cyanide or cyanuret of zinc is a powerful antispasmodic and tonic. No medicine is so potent in allaying irritability of the stomach, attended with great debility. The dose must be small and often repeated. Velerianate of zinc has lately been much recommended as a remedy against tic-douloureux and other nervous affections. Where the patients can tolerate the repulsive odour and persevere in its use, it often proves very serviceable.

Zinc pans have been much recommended for use in dairies, as the milk speedily coagulates in them, and the quantity of cream is great: but if the milk becomes sour while in them, the acid acts upon the zinc, and forms unpleasant, though perhaps not poisonous compounds. Upon the whole, white porcelain vessels, kept thoroughly clean, are the best material for milk-vessels.

ZINC MANUFACTURE. The mode of obtaining zinc from the sulphuret and other ores is explained in the article ZINC. As brought to market, commonly under the name of *spelter*, it is a bluish-white metal, having considerable hardness and toughness. The chief English supply is from Flintshire and the Isle of Man; but the market is mostly supplied from Upper Silicia, where the ore is smelted, and the spelter sent for shipment from Dantzic, Stettin, and Hamburg: shippers are willing to convey it freight-free, to serve as ballast for the ships that bring German wool to England. Mr. Robert Hunt has given the following as an account of the British ores of zinc brought up to the surface in 1857:—

Cornwall	1675	tons.	£4,697
Devon	775	„	2,478
Cardigan	1371	„	4,452
Isle of Man	2917	„	10,772
Cumberland	492	„	697
North Wales	2060	„	7,887
	9290	„	£30,983

presenting an average of about 66*s*. per ton. The largest mass of zinc ever described was that which was displayed at the Great Exhibition in 1851, and which weighed 16,000 lbs. It was smelted from the ore by Messrs. Detmold, of New Jersey, in the United States. There is a vein of zinc-ore 9 feet thick, at a spot about 50 miles from New York, and easy of access, as it is not far beneath the surface. The ore is carried to Newark, in New Jersey, where it is converted partly into metallic zinc, but mostly into zinc-white for house-painting. The metal is separated from the other ingredients of the ore by a process of vaporisation, as described in the article ZINC; but at Messrs. Detmold's establishment some of the operations are conducted in a remarkable way. A vapour, containing nearly all the zinc, is sent by blast along pipes to a *catching-house*, where it passes into enormous bags of cotton 5 feet in diameter by 150 feet long; the gases pass through the meshes of the bag, while an oxide of zinc cools down to the state of a white powder, which is shaken out of the bag at intervals. This is the mode adopted, not in procuring metallic zinc, but as the preliminary stage in making zinc-white. The powder is either sold in a dry state, in barrels containing 200 lbs., or is ground up with linseed-oil and sold in kegs.

In reference to the zinc-white above mentioned, it may be observed that the substance is recommended as a substitute for white lead in house-painting—not as being better suited in itself, but as being less injurious to the workmen. Some persons, moreover, attribute to it much greater permanency, and other qualities superior to those possessed by white lead. Linseed-oil and spirit of turpentine are mixed with the zinc-white. Oil in good proportion gives it durability and efficacy of covering the surface of the work; in excess, it has a softening and darkening effect. Turpentine in good proportion gives a ready fluidity for spreading; in excess, the paint becomes too transparent, and has a tendency to pulverise.

Metallic zinc is mostly used in the form of plates or sheets. When heated to a certain temperature it becomes malleable and ductile, and may then be rolled out to any convenient degree of thickness; and although brittle before this heating, the brittleness never returns after the cooling. This is found to be a valuable property in zinc. In the form of sheets, zinc is largely used for baths, cisterns, tanks, spouts, pipes, chimney-pots, roofing, as also for plates for engraving, sheathing for ships, and as one element in voltaic batteries. Being so much lighter than lead, zinc is found to be very useful for roofing. The joining of plates of zinc requires to be effected in a peculiar way. [SOLDERING.] In the making of zinc door-plates, a sheet of rolled zinc is cut to the proper size and shape, scraped to a clean surface, hammered flat, planished with a broad and smooth-faced hammer, and polished. Plates for zincographic engraving require, not a smooth, but a fine granular surface; they are rubbed first with ordinary sand, and then with fine sifted sand and water applied by means of a woollen rubber.

Many modes of coating iron and other metals with a thin layer of zinc have been described. Among these, one has been patented by Mr. Alexander Watt, editor of the 'Chemist.' Steel or iron is pickled in a solution of sulpho-muriatic acid, and then exposed to galvanic action in a battery supplied with cyanide of potassium, liquid ammonia, metallic copper, metallic zinc, hydrochloric acid, and carbonate of potash. This subject is further treated under TINNING.

The chief use of zinc, perhaps, is as a compound in the formation of brass. [BRASS.]

In 1860, metallic zinc, under the name of *spelter*, was imported from foreign countries to the extent of 24,000 tons.

ZINCAMIDE. [AMIDES.]

ZINC-AMYL. [ORGANOMETALLIC BODIES.]

ZINC-ETHYL. [ORGANOMETALLIC BODIES.]

ZINC-METHYL. [ORGANOMETALLIC BODIES.]

ZINC-WHITE. [ZINC; *Oxide of*.]

ZINCOGRAPHY. [LITHOGRAPHY.]

ZI'NGIBER OFFICINA'LE (GINGER), ***Medical Properties of.*** The native country of this plant seems unknown, though Goebel asserts that it is Guinea. It is however extensively cultivated in China, Java, and the East and West Indies. From the cultivated plant alone is the ginger of commerce procured. Of this there are two varieties, the black and white; but some writers affirm that these are the produce of two distinct species, while others ascribe the difference of appearance to diversity of treatment after the rhizome is dug up. The rhizome, or root-stock, is perennial, but it is only that of a young plant, or the annual shoots from an old one, which are met with in commerce. When first dug up, the colour internally is red. Those procured the first year are used fresh, or preserved in sugar, and constitute the sweetmeat known as *preserved ginger*. This, when sent from the West Indies, is in small, round, tender pieces; when from the East, larger, flat, and stringy portions: the former is preferred.

Black ginger is stated to be the rhizome dug up, scalded in hot water, and dried in the sun. White ginger is also scalded, and then scraped to free it from the rind before it is dried, which last operation is said to be effected by artificial heat, but probably mostly by the sun. Both kinds are very liable to the attacks of an insect. To prevent these attacks the rhizomes are dipped in a solution of lime, the white particles of which often adhere to the surface. To cause black ginger to resemble the white, it is bleached, after its arrival in this country, in a solution of chloride of lime, or exposed to the fumes of burning sulphur. This impairs the activity of the article.

Ginger occurs in commerce in pieces termed *races*, of various shapes, but generally flattish, branched, lobed, or palmated, rarely more than four inches long. The unscraped has a wrinkled epidermis; the scraped is devoid of this covering. Jamaica ginger, which is most esteemed in this country, occurs in races larger, rounder, and thinner than the other kinds; externally of a yellowish white, internally of a yellower hue. The taste is agreeably aromatic and pungent, but this is lost with age, so that old pieces are worthless, as are also portions which have been digested in alcohol to form *essence of ginger*. Ginger, when chewed, excites a flow of saliva; the powder applied to the nostrils causes sneezing. The quantitative analysis of 100 parts of ginger have been given by Buchols:—

Pale yellow volatile oil	1·56
Aromatic, acrid, soft resin	3·60
Extractive soluble in alcohol	0·65
Acidulous and acrid extractive, insoluble in alcohol .	10·50
Gum	12·05
Starch (analogous to bassorin)	19·95
Apotheme, extracted by potash	26·00
Bassorin	8·30
Woody fibre	8·00
Water	11·90
	102·51

Morin's analysis yields also acetic acid, acetate of potash, and sulphur, and a resin insoluble in ether and oils; while the ashes give numerous metallic salts and alkaline salts.

The volatile oil is of a pale yellow, lighter than water; taste at first mild, then hot. The soft resin, obtained by digesting the alcoholic extract of ginger first in water, then in ether, and evaporating the etherial tincture, is not quite analogous to the principle *zingiberin*, procured by Beral, and by him termed *peperoid*. This last is got by submitting ginger directly to the action of sulphuric ether. Beral recommends many preparations of this principle, but, except from their smaller bulk, it is difficult to perceive what advantage they possess over common ginger and its preparations. Ginger is an aromatic stimulant of considerable power. The effects are greater on organs with which it comes into direct contact than on remoter ones. Thus, when chewed, it is a powerful sialogue, and relieves toothache, rheumatism of the jaw, and also relaxed uvula. When received into the stomach, it promotes digestion in languid habits, and relieves flatulent colic. Gouty subjects are much benefited by it, and for such persons no form is more beneficial than that of preserved ginger taken at dessert after a mixture of viands. But it has the disadvantage of impairing the flavour of the wine taken at the same time.

The action of ginger on remote organs is greatest on the mucous membranes. Hence the lungs are markedly excited in the relaxed and suffocative catarrh of old people. The mucous membranes of the urino-genital organs are also excited by it in languid habits. Many feeble females receive much advantage from the domestic preparation termed ginger-tea. Some headaches of a sympathetic kind, originating in irritation of the intestinal canal, are often relieved by it. A poultice of scraped ginger, to which warm water has been added, forms a substitute for a mustard poultice, and often relieves headache when applied to the forehead. Ginger-beer is often a grateful beverage in summer heat, but with some persons it disagrees; this is owing to the sugar, for if made without it, it agrees with such persons well. Lemon-juice, when taken with sugar, often disagrees, as for example with pancakes. The lemon-juice alone is most wholesome.

ZIRCONIA. [ZIRCONIUM.]

ZIRCONIUM (Zr). A rare metal found in the minerals zircon and hyacinth, which contain the oxide of the metal united with silicic acid. To obtain the metal, the double fluoride of potassium and zirconium is to be strongly heated with potassium; from the cold residue diluted hydrochloric acid dissolves out everything except pulverulent zirconium, which must be washed first with solution of chloride of ammonium and then with alcohol. Zirconium has not yet been fused: obtained in the manner just described it presents the appearance of a black powder, which assumes a slight metallic lustre under the burnisher and scarcely conducts an electric current. Zirconium in this pulverulent form indicates the properties of the massive metal as little as pulverulent aluminium did those of the latter beautiful metal before it was obtained in malleable masses by Bunsen and Deville. When heated below redness in air or oxygen, zirconium takes fire and burns with a very intense light, producing zirconia. It is also gradually oxidised in boiling water, diluted hydrochloric and sulphuric acids do not act upon it, but hydrofluoric acid dissolves it with evolution of hydrogen. The equivalent of zirconium is 33·6 if zirconia be written Zr_2O_3, but if written ZrO_2 the equivalent is 22·4.

Zirconia (Zr_2O_3, or ZrO_2). Zirconium and oxygen form only one compound, zirconia, which is obtained by fusing finely-powdered zircon with caustic potash or soda and then dissolving the fused mass in dilute hydrochloric acid. Excess of acid and moisture are expelled by heat, when on the addition of water the chlorides of zirconium and potassium or sodium are dissolved, leaving insoluble silica; from this solution excess of ammonia precipitates zirconia as hydrate, which must be washed, dried, and ignited. It then presents the appearance of a white infusible and insoluble powder. The hydrate is gelatinous, insoluble in the caustic alkalies, but readily soluble in acids, and sparingly so in carbonate of ammonia.

Zirconia forms salts with acids, which possess the following characters:—They have an astringent taste; they are precipitated by the caustic alkalies potash and soda, and an excess of them does not redissolve the precipitate. When boiled with sulphate of potash, a subsalt of zirconia is formed, and being insoluble subsides. Infusion of galls produces a yellow precipitate, and phosphate of soda a white one: carbonate of zirconia, when recently precipitated, is soluble in bi-carbonate of ammonia and of potash.

ZO'DIAC (in Greek, *ὁ Ζῳδιακὸς κύκλος*, "the Zodiac circle") is a name given to a zone of the visible heavens, extending in breadth to certain equal distances on both sides of a great circle of the celestial sphere, in the plane of the earth's orbit produced. This circle, with which the apparent annual path of the sun coincides, is called the ecliptic; at present it makes, with the plane of the earth's equator, an angle equal to about 23° 27′ 35″, and it is divided into twelve equal parts, called *signs*, which receive their denominations from those of the figures intended to designate the constellations or groups of stars about it. Most of the figures being those of animals, the name of zodiac (from *ζῴδιον*, *zōdion*, the diminutive of *ζῷον*, *zōon*, "an animal") has, in consequence, been applied to the zone.

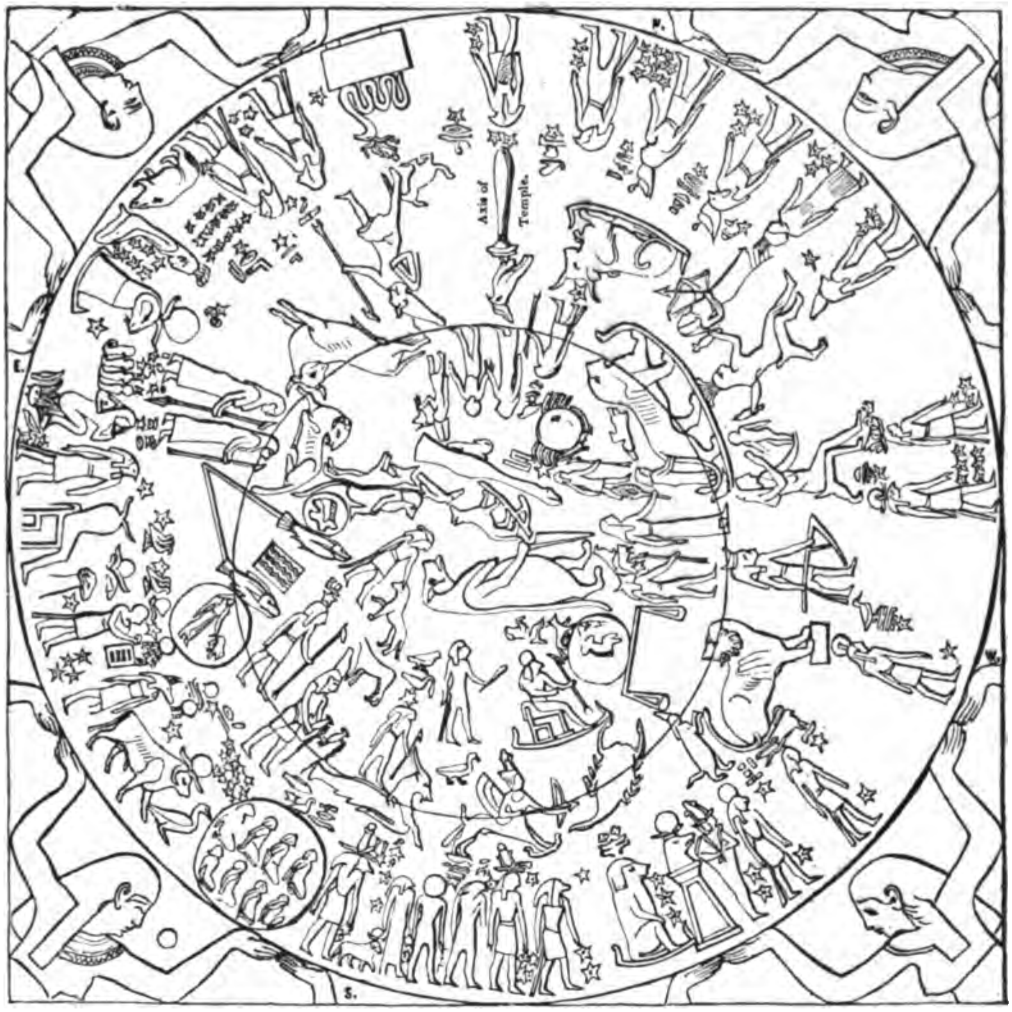
The planes of the orbits of all the planets, when produced to the celestial sphere, are supposed to be comprehended within the breadth of the zodiac, and that breadth is determined by two small circles parallel to the plane of the ecliptic. Before the discovery of Ceres, Pallas, and the other asteroids, the greatest inclination of the orbit of a planet to the ecliptic scarcely exceeded 7 degrees, and therefore the breadth of the zodiacal zone was imagined to be about 16 degrees, or 8 degrees on each side northward and southward of the ecliptic. The orbit of Pallas (that which deviates most from the ecliptic) is inclined about 35 degrees to that plane; and it might now be understood that the breadth of the zone is about 70 degrees.

The line in which the plane of the ecliptic intersects that of the terrestrial equator, being produced indefinitely, cuts the celestial sphere in two points diametrically opposite to each other; and one of these meeting the heavens, in the age of the earliest Greek astronomy, near certain stars forming a constellation to which the figure of a ram (Aries) was assigned, is generally called the first point of Aries. From this point are reckoned, on the ecliptic, the longitudes of celestial bodies; and on the equator, their right ascensions. The twelve equal parts or signs into which the ecliptic is divided are distinguished by the names of the constellations which, in the age above alluded to, fell within their respective extents in longitude; and the names both of the signs and constellations are as follow:—Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, and Pisces.

The distribution of all the visible stars into groups or constellations was the first step in laying the foundation of astronomical science. It must have taken place in the earliest ages of the world; and there is the highest degree of probability that the zodiacs of all nations have been derived from a common source, though in passing from one people to another it may be easily conceived that the figures would suffer changes from the vanity or caprice of individuals. Among the ancients, the place of the sun in the zodiac served to regulate the seasons of the year; the representations of the figures associated with the groups of stars were almost constant ornaments of the religious edifices; and superstition assigned to the regions of space influences on the lives and characters of men depending upon the qualities of the animals or objects which distinguished the constellations in the corresponding parts of the celestial sphere.

The loss of the writings of the ancient Babylonians, and the entire destruction of their edifices, have deprived the world of every monument by which light might be thrown on the state of astronomy among a people whose priests, according to Strabo, were mostly engaged in the study of the science. In fact, our information respecting it consists chiefly of the notices given by Ptolemy concerning a few of their observations, and from the evidence of Geminus. Diodorus Siculus states ('Biblioth. Histor.,' ii. 30) "that the Babylonians had twelve chief deities, to each of whom they assigned a month, and one of the so-called twelve animals," by which he means the twelve parts of the zodiac; and from this it may be inferred that they divided the zodiac into twelve signs. Sextus Empiricus ('Adversus Math.,' lib. v.) makes a like statement, and shows how, by means of a clepsydra, the division was or may have been made. With respect to the astronomical monuments which adorned their edifices, a few fragments only of stone, having on them figures which may or may not have been intended as representations of those which distinguish the constellations, have been dug up near Bagdad; and the most remarkable of these is one having on its face a solar disc accompanied by a serpent: the figure may have designated Ophiuchus, and it is possible that it may have been part of a Chaldæan planisphere. The division of the zodiac into twelve signs may have been originally made for the convenience of distinguishing the portions which the sun passes through in the several months; and a division into twenty-eight parts is alluded to by Geminus (*Εἰσαγωγὴ εἰς Φαινόμενα*), which was probably made to denote the space daily described by the moon by her proper motion. The former division was used by the Egyptians, the Greeks, and by all the civilised nations of Asia; and the latter is found among the Persians, Arabs, Hindus, and Chinese: the twenty-eight parts are called the *stations* or *abodes* of the moon, because this luminary is in some one of them each day.

During the invasion of Egypt by the French, in 1798, General Desaix discovered some remarkable sculptures on the ceiling of an apartment in the great temple at Denderah (the ancient Tentyra), and MM. Jollois and Devilliers almost immediately perceived among them figures nearly similar to those which are traced on celestial globes at the present time. The whole of the astronomical figures are within the circumference of a circle above five feet in diameter; and the apartment in which they were found is in the upper part of the building: adjoining it is an apartment of equal size, which is open to the sky, the ascent to both being by steps in the interior. Bas-reliefs, apparently of an astronomical character, are found in several other apartments within the same temple; and in the ceiling of its portico are figures resembling constellations, among which are those of the zodiac disposed in two lines, one near each extremity of the portico, and parallel to the longitudinal axis of the temple.



The zodiacal figures in the apartment first mentioned are disposed nearly within the breadth of an annulus formed by two circles, whose common centre is at some distance southward from the centre of the whole; the figure which is conceived to represent Cancer is however within the space inclosed by the interior circumference of the annulus, and nearly opposite the interval between Gemini and Leo; that interval being occupied by a human figure with a bird's head, above which are a bird and certain hieroglyphical symbols. The figure of Cancer is also surmounted by a hieroglyphical symbol, which, according to Visconti, seems to express a proper name.

Except the zodiacal figures, scarcely any in the ceiling resemble those which are now assigned to the constellations; and a great effort of the imagination is required to discover in what manner they may be considered as emblems of the latter. From the zodiacal figures only has it been possible to form opinions concerning the nature of the projection employed in the execution of the work, and the epoch to which the aspect of the heavens represented by it is to be referred.

The first discoverers of this ancient monument immediately perceived that the horary or declination circles, if drawn upon it, would be represented by straight lines diverging from the centre: the latter is consequently the pole of the equator; but we are indebted to M. Biot (' Recherches sur l'Astronomie Egyptienne') for the very probable idea that the space within the exterior circle represents a development of the whole surface of the celestial sphere, the radii of the circle being equal to half the circumferences of the hour circles, so that the exterior circle represents the south pole of the equator in the heavens. The figures of the constellations are supposed to be placed on the radii corresponding to the circumferences of the hour circles passing through the groups of stars to which the figures belong, and at distances from the centre of the planisphere equal to the angular distances of the figures from the north pole of the equator. The distortion produced by such a development of a spherical surface is evidently very great near the margin; but a spectator when duly instructed, on comparing the figures near the centre with the groups of stars about the north pole in the heavens, might distinguish those to which the figures were intended to refer; and the apartment without a roof, adjoining that which contained the planisphere, is supposed to have been intended for the purpose of facilitating such comparison. One property of the species of projection or development just mentioned is, that in the direction of a line passing through the centre, or pole, the distance between two points corresponding to two which are diametrically opposite to one another in the heavens is equal to half the circumference of a great circle of the sphere; and M. Biot found that this condition is satisfied by the planisphere as nearly as can be expected in a representation which does not admit of great precision.

In order to ascertain, if possible, the epoch of the planisphere, M. Biot assumed as correct the positions of four stars upon it, which, being accompanied by figures of men and by hieroglyphical symbols, appeared to have been distinguished on account of some particular interest attached to them; and concluding from their positions with respect to the nearest zodiacal signs that they must represent Fomalhaut, Antares, Arcturus, and β Pegasi, he first verified them by the near agreement of their measured distances from each other on the planisphere with the distances obtained by computation from their known angular distances in the heavens; then computing the angles of the triangle formed by two of the stars and the centre, or pole, of the planisphere, and also the angles of the triangle in the heavens between the arcs joining the two stars and the pole of the ecliptic in 1750, he found, by comparison, the latitude and longitude of the centre of the planisphere with respect to the positions of the ecliptic and the equinoctial point for that year. The position of the centre, thus found, is that which the pole of the world must have occupied about the year 716 B.C.; and he thence concludes that the planisphere presents the state of the heavens at the latter epoch. M. Biot afterwards calculated for that epoch the places of the principal stars, and determined their situations on a plane by the rules of the projection supposed, as above mentioned, to have been used in constructing the Egyptian monument: on comparing the map so formed with an exact copy of the planisphere, he found the stars to fall upon or near the figures to which they were presumed to belong. Thus the stars of Ursa Minor fall near the centre, precisely on the figure of an animal resembling a dog or wolf, probably the Cynosura of the Greeks; and those of Orion on the figure of a man, apparently intended for Horus, the son of Osiris, to whom, according to Plutarch ('De Iside et Osiride'), Orion was consecrated.

Several indications exist in the planisphere of an intentional displacement of the figures designating the constellations. In some cases, apparently when a constellation could not be conveniently introduced in its proper place for want of room, it has been transferred to the margin in the direction of a line drawn from the centre through the true place of the constellation. In other cases a constellation appears to be removed and a hieroglyphic figure substituted for it. Thus a line drawn from the centre of the planisphere, through Taurus, leads near the margin, to a group of seven stars, which probably designate the Pleiades; and near it is another group, which may represent the Hyades. Again, between Aries and Pisces, and a little above them, is an animal in a sitting posture, which is found to coincide with the computed places of the stars in Cassiopeia; and near the margin of the planisphere in a line drawn through the centre and this animal, there is a human figure seated in a chair, as Cassiopeia is always represented. In a few cases some emblem of a constellation is found at the margin opposite the figure denoting the constellation: thus the head of a ram surmounted by a winged globe is in the direction of a line drawn from the centre through the front of Aries in the zodiacal ring. A great figure, which is supposed to represent a hippopotamus, is situated near the centre of the planisphere in a place corresponding to a part of the heavens very near Ursa Major, but where there are no remarkable stars; and M. Biot conjectures that the animal may be an emblem of that constellation: he conceives that it may indicate Typhon, who, according to Plutarch ('De Iside'), is represented by a hippopotamus, and to whom Ursa Major is assigned. That the ancient Egyptians had a constellation which was designated by this name is stated by Plutarch and by Diodorus Siculus (i. 27); the latter has given translations of two inscriptions in hieroglyphics, which appear to have existed in his time; and in one of these Osiris is made to say that he had been to the uninhabited parts of India, to the regions of the *Bear*, and to the sources of the Ister (Danube).

In the direction of a line drawn from the centre of the planisphere, towards the north, and passing through the figure of Cancer, is the representation of a cow having a great star between its horns; and near it, in the direction of a line coinciding with the longitudinal axis of the temple, is a tall lotus-stem surmounted by a hawk, the symbol of deity. On this stem the place of Sirius, computed for the epoch of the planisphere, is found to fall; and the cow probably represents Isis, to whom the star Sirius was consecrated. The solsticial colure being due north and south, it is probable that the planisphere was intended to show the aspect of the heavens at the time of the vernal equinox, when the colures pass through the four cardinal points of the horizon; and the line passing through Cancer and the cow being in the plane of the solsticial colure is an indication that at midsummer, at the epoch of the planisphere, Sirius rose with the stars of Cancer. The line representing the direction of the equinoctial colure passes, on the eastern side, between two symbolical figures of men, a little way from which is a small figure (supposed to be Harpocrates) issuing from a lotus-flower, and having above his head a star with a hieroglyphical inscription. According to Plutarch ('De Iside') the Egyptians represented the rising sun by a child issuing from a lotus; and hence it is inferred that the symbols indicate the rising of the sun in the east point of the horizon on the day of the vernal equinox.

The heads of all the figures, with scarcely an exception, tend towards the centre of the planisphere, and the figures in the southern half of the zodiac are arranged so that, to a spectator standing in the centre of the room with his face to the south, and looking upwards, they must have appeared as if moving from east to west; that is in the direction of the apparent diurnal motion of the heavens. The longer axis of the temple is inclined to the meridian in an angle of about 17 degrees, and the walls are directed so that the points at which the remarkable stars Sirius and Antares must have seemed to rise coincided with the directions of the north and south ends of the building. A temple near Esne (Latopolis), in the portico of which is a representation of the zodiacal signs, is disposed so that the longitudinal walls tend to the points at which Antares and Sirius set; and though no great stress ought to be laid upon this circumstance, there is some probability that the dispositions may have been intentional, since no reason can be assigned why, otherwise, the temples should not, like the pyramids, have had their walls directed to the cardinal points of the horizon. The golden circle of Osymandyas, which is mentioned by Diodorus Siculus (i. 49) as being placed in the tomb of that ancient king at Thebes, was 365 cubits in circumference, and to each cubit was assigned one of the 365 days of the year, with the risings and settings of the stars for each day marked on the several divisions.

The ceiling of the portico belonging to the temple at Denderah is nearly covered with sculptured figures, many of which resemble those in the circular planisphere, and the twelve signs of the zodiac are distinctly represented in two bands parallel to the axis of the building: six of the figures appear to be entering the temple on the eastern side of the portico, and of these Cancer is the last; the other six, of which the first is Leo, appear to be quitting it on the western side, so that (the front of the portico being towards the north) the direction of their motion corresponds to that of the apparent diurnal rotation. Within the two lines of figures are those which belong to the northern constellations, and beyond them, near the eastern and western extremities of the portico, are figures relating to the southern constellations. Among the former is a human figure surrounded by seven stars, disposed similarly to those of Ursa Major in the heavens, and near them is a lotus-stem surmounted by a hawk, like that which in the circular planisphere is in the place of Sirius: this emblem in the planisphere of the portico is therefore supposed to be an indication of Sirius; and the opinion is confirmed by the fact that it is preceded by a cow (Isis) and a great hieroglyphical inscription.

In the planisphere of the portico, as well as in that of the temple, the figure supposed to be that of Cancer is placed on one side of the position which it should occupy among the zodiacal constellations; and this circumstance has given rise to a doubt concerning the justness of that supposition. Some persons have imagined that the figure might have been intended for the mythological scarabeus; but as in this temple, as well as in those at Esne, it has eight feet, while the scarabeus has but six, it is more probable that it represents the zodiacal sign; and that, agreeably to the hypothesis of Biot, the displacement was in order to make room for some emblem. In fact, the place of Cancer is, in the portico, occupied by a head of Isis, which is plunged in the solar rays; and, since Sirius was consecrated to Isis, it is reasonable to suppose that the emblem was intended to express that, at the epoch of the planispheres, the star Sirius rose heliacally. By calculation it is ascertained that about 700 years before Christ, in the latitude of Denderah, Sirius rose with the star of Cancer when the sun was in that constellation, that is, at the summer solstice.

The two temples at Esne have, in the ceilings of their porticoes, representations of the twelve zodiacal constellations in two lines parallel to the axes of the buildings. In the smaller temple six of the figures appear to be entering on the southern side, and six to be issuing on the northern side: the front of the portico being towards the east, the direction of their movement corresponds, consequently, to that of the diurnal rotation, as in the temple at Denderah; but there is this difference in the division of the figures, that at Esne, Leo is the last to enter, and Virgo the first to quit the temple. M. Biot endeavours to account for this difference by the different inclinations which the axes of the two temples have to the meridian; the axis of the temple at Denderah deviating 17 degrees, and that of the small temple at Esne 71 degrees, both of them being from the north towards the east. He observes that, in the former temple, a meridian line passing through the centre of the circular planisphere cuts the zodiacal band in Cancer towards the north, and in Capricorn towards the south; thus dividing the twelve figures so that the six which are on the western side constitute all those which at a certain hour are descending towards the west, and those which are on the eastern side are ascending towards the meridian. At the head of this descending series is Leo, which is the first to pass the inferior meridian and enter the eastern series; and at the head of the ascending series is Aquarius, which is passing the upper meridian: this distribution corresponds to that which is represented in the zodiac of the portico. A like correspondence would be found to exist in both the temples at Esne if a circular planisphere were supposed to be placed in the ceiling of each, with the lotus-stem in the longitudinal axis, towards the north, and the planisphere were cut by a meridian-line so as to divide the figures into such as ascend and such as descend.

That there were among the ancient Egyptians a variety of sculptured representations of the heavens is evident, since the planisphere described by Scaliger, in his 'Notes on Manilius,' contained, among many animals having no correspondence in form or situation with those which have been mentioned, the figure of a man holding a scythe, and of another who is killing a bear; and in the 'Mémoires de l'Académie des Sciences,' 1708, there is described, by M. Bianchini, a fragment of an Egyptian planisphere consisting of a circular space surrounded by five concentric bands: in the centre are two bears separated by a serpent, as in the present spheres; and in the nearest band are twelve figures representing constellations, most of which differ from the zodiacal signs above described; the place of Gemini, for example, being occupied by a serpent. In the two next bands are the signs of the Greek zodiac, and on the exterior of these is a band divided into 36 parts, in each of which is a deity; these are the spaces of 10 degrees, into which, in the East, the zodiac was sometimes divided.

There can be little doubt that the Egyptians and Chaldæans distinguished the groups of stars in the visible heavens by the figures or symbols of the deities which they worshipped, and of the men who, among them, had signalised themselves by great actions; but it has been also assumed, that the names of the zodiacal constellations were given from circumstances relating to the apparent motion of the sun, to the labours of husbandry, or to the productions of nature in different seasons. Macrobius mentions ('Saturnal.,' lib. i.) that the constellation in which the sun is, at the season when he ascends from the winter solstice towards the equator, received the name of Capricronus, because the goat is an animal accustomed to ascend to the highest points of ground; and that the constellation in which the sun is when he returns from the summer solstice towards the south was designated

Cancer from the crab being an animal which is said to have a backward movement. Bishop Warburton in this country, and M. Pluché in France, carrying out the same idea, have imagined that the constellations Aries, Taurus, and Gemini received their names from the young of animals being brought to the fields in the spring; that Leo indicates the violent heats of summer, and Virgo, presumed to be a gleaner, denotes the time of harvest, and so on. M. Dupuis, assuming that the zodiacal constellations were first imagined in Egypt, and that they indicated circumstances connected with the labours of husbandry in the different months of the year, endeavoured to ascertain at what epoch, in the climate of Egypt, the symbols would be in accordance with the circumstances which they were supposed to represent; and the result of his inquiry was, that the agreement could have subsisted only when the vernal equinox was in the constellation Libra. At present it is in the constellation Pisces; and computing the time during which, by the effect of precession, the equinoctial points would move over about half the circumference of the ecliptic, he assigned 15,000 years before the Christian era for the time of the invention of the zodiac. This extravagant epoch he afterwards reduced to about 4000 years before Christ. ('Origine des Cultes,' 1796.)

M. Fourier, in his 'Recherches sur les Sciences et le Gouvernement de l'Egypte,' assumes that the representation of the head of Isis partly plunged in the solar rays near the figure of Cancer, among the sculptures in the portico of the temple at Denderah, is an emblem of the heliacal rising of Sirius when the sun was in the sign, or in the constellation Cancer; and observing that Cancer is the last of the figures which appear to enter the portico of that temple, while in the zodiacs at Esne the lion is the last which enters, he conceives that the latter circumstance is an indication of the sun being in Leo when Sirius rose heliacally. Supposing, then, that the epochs of the zodiacs at Denderah and Esne are such as the positions of the sun denote, he determines, by computation founded on the progressive displacement of the point of the heliacal rising, that the interval between them is 1800 years, the sculptures at Esne referring to the more ancient period. This result must, however, be considered as overthrown by the calculations of MM. Ideler and Biot, who have determined the longitudes of the sun at the terminations of three sothiac or canicular periods of 1460 years, within which the heliacal risings of Sirius return to the time of the summer solstice; and have found that between the year 2782 B.C. and 139 A.C. the sun was in the constellation Leo and in the sign Cancer at all the three epochs. M. Biot concludes therefore that the zodiacs at Denderah and Esne do not indicate that the sun had passed from one constellation to the next in the interval between the epochs to which they are supposed to refer.

In the temple at Denderah, according to Dr. Young, Leo may be intended to represent the leading sign of the zodiac, or the sign preceding that in which the sun was on the first day of the *annus vagus* (year of 365 days); and on this supposition it would follow, from the known rate at which the place occupied by the sun in the ecliptic at the commencement of such year retrogrades, and also from the fact that the year of 365 days began on the day of the vernal equinox in the year 130 B.C., that the epoch of the planisphere is between 11 B.C. and 108 B.C., or in an age earlier by 1500 years. If Virgo were the leading sign, as it may be supposed to be in the small temple at Esne, the epoch of the zodiac would be the year 900 B.C., or 1500 years earlier.

It has been ascertained by MM. Champollion and Letronne from the Greek inscriptions on the temples of Denderah and Esne, that those edifices were constructed, or finished, during the times of the Roman emperors ('Précis du Système Hieroglyphique, Recherches, &c.'); yet, as it is known that during the reigns of the Ptolemies, and even after the conquest of the country by the Romans, the Egyptians continued to build temples, which they consecrated to their deities, with decorations similar to those which were executed in more ancient times, it may be presumed that the present sculptured zodiacs are copies of others which were the works of the earliest artists; so that though they determine nothing respecting the time of the construction of the temples, they may still serve as indications of the manner in which the heavens were represented in the East in the infancy of astronomical science. The circular planisphere which once adorned the interior of the temple at Denderah was removed to France in 1821.

The country from whence the Greeks derived the figures of the constellations is not with certainty known: that all the extra-zodiacal signs in their descriptions of the heavens did not, from the first, receive their designations from subjects connected with the Greek mythology is evident, since in the notices given by the earliest writers on astronomy, two of them, which subsequently received the appellations of Hercules and Cygnus, have the general names *ἐν γόνασιν, a kneeling figure*, and *ὄρνις, a bird;* and that some of the figures were borrowed from the Chaldæans is probable, since in the time of Herodotus it was supposed that the Greeks acquired from the Babylonians the knowledge of the *polus* (*πόλος*), the gnomon or style, and the division of the day into twelve parts. (Herod., ii. c. 109.) It may be imagined that, from the intercourse between the Egyptians and Greeks in very early times, a great resemblance should be found among the figures employed by the two people to represent the groups of stars; but that they differed in some respects from one another may be inferred from the testimony of Achilles Tatius, who states that the Egyptians had not the constellations Draco, Cepheus, and Cassiopeia; and it follows that these must have been introduced by the Greeks, or at least that the latter people substituted them for corresponding figures in the Egyptian sphere. It may be remarked, however, that in the oldest descriptions of the Greek zodiac *σκορπίος* and *χηλαί*, the *scorpion* and the *claws*, make one constellation; whereas in the Egyptian zodiacs the corresponding part of the heavens is divided between the scorpion and the balance, the latter occupying the place of the claws. Now in a work on the "constellations," ascribed to Eratosthenes, who lived in the time of Ptolemy Euergetes, it is stated that the great length of the constellation caused astronomers to divide it into two parts; and in a poem attributed to a certain Manetho, supposed to be the priest of that name, and dedicated to one of the Ptolemies, it is expressly stated that "the claws of Scorpio' were by the priests changed into "the balance." It would seem therefore that the Egyptians, in or before the time of Manetho, adopted in their zodiac a name which had been given by the Greeks: yet as an argument in favour of the great antiquity of the sign it may be observed that, according to Ptolemy, the Chaldæans designated by a word signifying a balance the constellation called by the Greeks *χηλαί*: it may be, however, that he alluded then to the Chaldæans of his own time.

The designations which are given to the constellations in the writings of the Greeks apparently indicate persons or objects connected with the Argonautic expedition; and it is reasonable to suppose that, about the epoch of that expedition, the Greeks, having acquired a knowledge of the manner in which the Chaldæans or Egyptians represented the visible heavens, transformed such of the figures as they did not reject into others having relation to the actions of their own heroes. On this hypothesis it has been assumed that Aries represents the ram whose golden fleece was the object of the expedition; Taurus, the bull or bulls which were tamed by Jason; Gemini, Castor and Pollux, and so on. The ship, among the southern constellations, is supposed to be the Argo; and Ursa Major, the nymph Callisto. The history of Perseus is imagined to be represented by Perseus, Andromeda, Cepheus, Cassiopeia, and Cetus; and the labours of Hercules, by Draco, Leo, and the constellation bearing the name of that hero. Newton, in his 'Chronology,' appears however to assume too much when he considers that Chiron, whom he supposes to have given the names to the constellations, disposed Aries, Cancer, Libra, and Capricornus so that the equinoctial and solsticial colures passed through their middle points: the precise determination of these points was beyond the science of the Greeks long subsequently to the age of Chiron.

Hesiod mentions ('Opera et Dies') the Pleiades, Arcturus, and Orion, stating that land should be ploughed at the heliacal setting, and corn reaped at the heliacal rising of the Pleiades (about the middle of April); he directs also that corn should be threshed at the rising of Orion, and vines pruned when Arcturus rises in the evening. Homer also mentions the Pleiades, Hyades, the Bear or Waggon,

ἄρκτον θ' ἣν καὶ ἄμαξαν ἐπίκλησιν καλέουσιν,

and Orion in the description of the shield of Achilles ('Il.,' xviii., 487); it is evident therefore that already in the time of Homer those constellations were introduced in the sphere of the Greeks. Plutarch asserts that Anaximander (probably about 600 B.C.) constructed a dial; and that representations of the clusters of stars, together with figures of the constellations, were frequently executed in Greece in the time of Hipparchus, is evident from a passage in the commentary of that astronomer on the poem of Aratus: planispheres, he observes, are constructed for men's use, and therefore the figures on them are traced just as they appear in the heavens to the view of the spectator.

In the work of Autolycus, entitled 'On Risings and Settings' of the Stars (*περὶ Ἐπιτολῶν καὶ Δύσεων*), and in the 'Phænomena' (*Φαινόμενα*) of Euclid, the signs of the zodiac are mentioned, and the parts into which that band of the heavens was divided are called dodecatemories, or twelfths; but it is in the astronomical poem of Aratus that the most complete knowledge of the celestial sphere of the Greeks is to be obtained. This writer lived about 270 years before the Christian era, and his poem is a paraphrase of two works which were composed by Eudoxus of Cnidus, who lived 100 years previously, that is, in the age of Autolycus and Euclid.

In describing the constellations, Aratus begins with those immediately about the north pole of the equator, and proceeds from thence to the zodiac, nearly in the directions of the declination or hour-circles of the sphere. He mentions Ursa Major and Ursa Minor, observing that they are placed so that the tail of one corresponds to the shoulders of the other, and he adds that the constellation Draco winds between them. Near the head of Draco he places the figure of a man, who is said to be on his knees (Hercules, whose attitude has since been changed), and behind him the northern crown. Near the kneeling figure is Ophiuchus, the serpent-carrier, and under the latter are the great claws (of Scorpio). Behind Ursa Major is Arctophylax (Bootes), with the star Arcturus below his girdle; and under his feet is the constellation Virgo. Near the head of Ursa Major are Gemini (*Δίδυμοι*); under his body is Cancer, and under his feet Leo. Auriga and the star Capella are said to be on the left of Gemini, opposite Ursa Major; and at the foot of Auriga are the horns of Taurus, whose head is indicated by a cluster of stars (the Hyades). Cepheus is behind Ursa Minor, and near him is Cassiopeia, the stars of which are said to be arranged in the form of a key: Cassiopeia has her hands raised above her head as if bewailing the fate of her daughter Andromeda, who is placed below her. The arms of the latter are extended and chained (to a rock); and under her head is Pegasus. Aries is below the girdle of Andromeda, and, as well as the claws of Scorpio and the girdle of Orion, it is in the equator; the triangle (δελτωτὸν) is above Aries. The constellation Pisces is below the triangle; and Perseus stands with his hand near the chair of Cassiopeia. Below his left knee are the Pleiades, and the names of the seven daughters of Atlas are given to the stars of the cluster. Aratus observes that there are but six stars in the cluster; but Hipparchus, in his commentary on the poem, states that against a dark sky seven may be seen. The bow of Sagittarius tends towards the tail of Scorpio. The Lyre, and the eagle which carries it, is between Perseus and the head of the bird (ὄρνις). (This is the constellation Cygnus, which also by Manetho and Ptolemy is called the Bird. The name Cygnus is first applied to it in a work on the constellations which is ascribed to Eratosthenes.) Cygnus extends towards the other eagle (Aquila), and near the head of Pegasus is the right hand of Aquarius, which, it is remarked, rises before Capricornus. Over the latter is the Dolphin. All the above constellations are stated to be between the zodiac and the north pole; and the zodiacal constellations are afterwards mentioned in order, beginning with Cancer and ending with Gemini. Libra (elsewhere called ζυγόν) is not mentioned, while Scorpio and the Claws are described as if they formed two constellations.

In the description of the constellations between the zodiac and the south pole, it is stated that Orion is placed obliquely to Taurus, and that Canis Major is at his feet. Under him is said to be Lepus, and at the tail of the dog is the head of the ship Argo. Under Aries and Pisces, and above the river (Eridanus), Cetus advances towards Andromeda, and below Capricornus is the Southern Fish. Under Sagittarius is a circle of stars (the Southern Crown), and below the sting of Scorpio is the Altar. Under the Scorpion is Centaurus, while farther on is Hydra, having its head under Cancer, and its tail above Centaurus: about the middle of its body is Craterus, and near the tail is Corvus. The bright star Procyon is under Gemini.

Such, nearly, is the description given by Aratus of the celestial sphere; and the constellations are, in general, the same as those which are represented on the modern globes. Some inconsistencies which exist in it were pointed out by Hipparchus, who lived about 100 years before Christ, and wrote a commentary on the poem. It is plain that the descriptions have been compiled from observations made by persons at different places, and probably in different ages; for in one part of the work it is stated that the extremity of Draco, and in another the girdle of Cepheus, touches the horizon, while in a third place Bootes is said to go below that circle, except his hand: and these circumstances are quite incompatible with observations made in the same latitude. It should be remarked that, in the Greek sphere, the stars are not always placed in the same parts of the figures as they occupy at present: thus the principal star of Aries is placed by Hipparchus in the front foot of the animal, while on the modern globes it is placed in the head.

It would be desirable to ascertain from the poem of Aratus the position of the equinoctial or solsticial points, in order to find the epoch of the observations on which the description is founded, but it is to be regretted that nothing satisfactory can be discovered concerning the subject. It is stated in the poem that the southern tropic cuts the middle of Capricornus, and hence the equinoctial colure should pass through the middle of Aries. Now, in the presumed age of Eudoxus, the first remarkable star γ in Aries was nearly at the point in which the trace of the ecliptic in the heavens cuts that of the equator; and if we suppose the extent of the constellation to be 30 degrees, the middle point, reckoning from that star, would be nearly at the 15th degree of longitude. The longitude of that star is now about 30°, and hence the equinoctial colure would have retrograded as much as 45 degrees, which at the known rate of the precession would take place in about 3200 years: consequently the epoch would be about the year 1400 B.C. Or, if with Ptolemy it is supposed that the extent of the constellation between the first star γ of Aries and the first star of Taurus (now δ Arietis) is only 18 degrees, the middle point would be in the 9th degree of longitude, and the retrogradation would be 39 degrees, which would place the epoch about the year 970 B.C. Nothing, however, can be more uncertain than conclusions drawn from such data.

The taste for ornamenting buildings with sculptures representing astronomical subjects appears to have existed in ancient Rome, as well as in Egypt and in the East; for in 1708 a fragment of a planisphere was discovered in that city. It has in its centre a serpent, probably an emblem of time, and near it two animals, apparently bears; about the serpent are the remains of three concentric rings, divided into compartments containing figures, among which are some of the zodiacal constellations.

That the Romans adopted the Greek sphere is evident from the descriptions of the constellations in the 'Astronomicon' of Manilius: those of the zodiac, in particular, are given in the verses "Aurato princeps aries in vellere fulgens," &c.; and the poem contains a detailed account of their astrological dispositions and qualities. The twelve signs are divided into masculine and feminine alternately, and are appropriated to different deities. There is also a division of the zodiac into twelve parts, which are designated Athla, or labours, and relate to the occupations or professions of men (lib. iii., v. 93). Four constellations, comprehending a space equal to one-third of the circumference of the zodiac, are said to constitute a trigon; three a tetragon, and so on; and there are four trigons arising from the different constellations, which may coincide with the angles of an equilateral triangle supposed to be inscribed in the zodiac: the like is to be understood with respect to the tetragon, hexagon, &c. Each sign of the zodiac is supposed, in the poem, to give a certain number of years to the life of a man; and his profession or fortune is imagined to depend on the particular sign which is rising at his birth, according to the qualities or uses of the animal by which the sign is distinguished (lib. iv., v. 122). It is also asserted that the characters of men depend on the qualities of the extra-zodiacal constellations: thus, persons born when the ship Argo rises are said to become seamen or to have an interest in naval affairs (lib. v., v. 39).

Scaliger, in his notes on Manilius, has given, from a manuscript of Aben-Ezra, a description of three planispheres, of which one is supposed to have related to the astronomy of the ancient Persians, and another to that of the Hindus; the third is supposed to be either Egyptian or Greek. The significations of the figures in the Persian sphere are very uncertain; but among those which have been recognised are Ursa Major and Ursa Minor, and a winged horse, besides Virgo, Leo, and Taurus. The figures of men and women are without designations; but among the former is one on a throne, which is thought to represent Cepheus, and one in a kneeling posture, which may be Hercules; of the latter, there is one which is presumed to represent Cassiopeia or Andromeda. A figure of a ship is also distinguished. It is asserted in the 'Zend-Avesta' [ZEND-AVESTA] that the ancient Persians divided the zodiac into twenty-eight constellations, or houses of the moon, and also into twelve signs: to these last are assigned names which correspond to those at present given to the constellations in that region of the heavens; and the cluster called the Hyades (in Taurus) is described as a bull with gilt horns. The division of the zodiac into twenty-eight lunar mansions prevailed also among the Arabian astronomers in or before the 9th century. It is mentioned by Alfragan, who states ('Elementa Astron.,' A.D. 850) that the first was called Xartan, and that it commenced near the three principal stars in Aries.

The Hindu zodiac, which is described in the 'Philosophical Transactions' for 1772, consists of twelve figures disposed on the four sides of a square. In this the place of Gemini is occupied by a figure of a man apparently with a shield on each arm; Virgo is represented by a female figure naked and seated; Libra is represented by a pair of scales similar to those in common use at present; and in place of Capricornus are figures of a ram and a fish, which are close together, but do not, as in the modern sphere, constitute one body. A globular vessel represents Aquarius; and for Pisces, one fish only is delineated. The figure in the place of Scorpio cannot be made out. This remarkable monument was discovered in the ceiling of a choultry or pagoda at Verdapettah, in Madura; and the separation of the figures in Capricornus seems to indicate that it is of great antiquity, as it may be reasonably supposed that such a disposition preceded in order of time that of a union of the two bodies in one.

In the second volume of the 'Asiatic Researches' there is given, by Sir William Jones, a paper containing a description, from the Sanskrit of Sripeti, of an ancient zodiac, which is divided into twelve parts, each of 30 degrees, corresponding to the modern signs. The ram, the bull, the crab, the lion, and the scorpion are said to have the figures of those animals, and in the plate which accompanies the memoir the entire figure of the bull is given: the twins consist of a male and a female figure, and in the description, the woman is said to play on a musical instrument, while the man holds a club, but the figures are not so represented in the plate. Virgo is represented by a woman in a boat; in one hand she holds a lamp, and in the other a blade of corn. Libra is represented by scales, which are held by a man who appears to be placing a weight in one of them. Sagittarius is the figure of an archer, whose legs are like those of a horse. Capricornus is the figure of a gazelle. Aquarius is represented by a man pouring water from a vessel which he carries on his shoulders; and lastly, Pisces consists of two fishes, the head of one being turned towards the tail of the other. The zodiac is also divided into twenty-seven parts, constituting the mansions of the moon: these are not represented in the plate, but their names, as well as those of the twelve signs, are given. The age in which Sripeti lived is unknown.

The Zodiacs of India and of ancient Persia may be presumed to have been originally the same as that of the Greeks or Egyptians; for although all of them differ from one another in the details, the points of coincidence are too numerous to be accidental, and it is probable that in the course of time the primitive sphere was altered in the countries eastward of Egypt and Chaldæa, as it was by the people of Europe. On the subject of the Indian zodiac the reader may consult Bohlen, 'Das Alte Indien,' vol. ii., p. 252, &c., and the references in the notes.

The representations of the heavens which have been found among the people of northern India, China, and Japan correspond to those which were in use in the western parts of Asia, in the zodiac being divided into twelve parts, which are called mansions of the sun, and also into twenty-eight parts; but, according to the accounts of the Jesuit missionaries, the Chinese at one time gave to these the names of the seven planets, each of which was repeated four times. In the ancient Chinese histories mention is frequently made of machines exhibiting the apparent movements of the heavens; and Père Mailla has given a plate representing a sphere which is supposed, though without sufficient reason, to have been executed about the year 2285 B.C. From those histories it appears that the Chinese were, at a time long prior to the commencement of the Christian æra, instructed in astronomy by a people from the west; and it is therefore probable that they thus acquired a knowledge of the method followed by the Persians and Arabians in the division of the zodiac. A table of the twenty-eight constellations into which the Chinese have divided the zodiac, with their names and the extent which each occupies, is given in Delambre's 'Histoire de l'Astronomie' (tom. i., p. 380), from the work of Père Souciet entitled 'Observations Mathématiques Astronomiques,' &c., 1729; and it is stated that the first, which is named *Pi*, commenced, in 1683, with the fourth degree of Aries. Delambre has also given a table of the twelve constellations; and from the records of the eclipses which the Chinese have observed, it is evident that the place of the sun has always been referred by that people to the signs of the zodiac. From a very early period they made their year commence when the sun is near the winter solstice, and they designated that part of the zodiac the resurrection of the spring, or of the year. The rat, the bull, the leopard, the hare, the dragon, the serpent, the horse, the sheep, the ape, the hen, the dog, and the hog are names supposed to be given, both in China and Japan, to the zodiacal signs; but it is more probable that they are applied to the twelve years of a cycle which is frequently used in the east, or to the twelve hours into which, in those countries, the day is divided.

The extra-zodiacal stars are distributed in constellations, which are distinguished in general by the names of the emperor and his ministers or courtiers; but that which in Europe is designated Ursa Major is represented by a vessel for measuring corn; the four stars of the quadrilateral figure forming the body and the others the handle. Biot relates, from information communicated by M. Remusat, that in the Chinese sphere the constellation which corresponds to Orion is designated by a name signifying a conqueror.

That a few coincidences should exist among the names given by different people to the groups of stars in the heavens, may be conceived without supposing that any of the people borrowed from one another: it may, therefore, be considered as purely accidental that the Iroquois called the stars of Ursa Major by a name which in their language signifies a bear (Lafitteau, 'Mœurs de Sauvages,' tom. ii.), and that the people living about the Amazonas designated the stars in the head of Taurus by a word signifying a bull (Condamine, 'Mémoires de l'Académie des Sciences,' 1745). But it is remarkable, and may be deduced as a proof, among many others, of the descent of the ancient Mexicans from the people of Asia, that the former should have executed sculptured representations of their calendar, and placed them as ornamental objects in their religious edifices. It has been ascertained that the Toltecans and Aztecs made the year consist of eighteen months of twenty days each, to which they added five complementary days, introducing a period of thirteen days at the end of fifty-two years in order to complete the cycle [Aztecs, in Geog. Div.]; and this division of the year is represented in a chronological table executed by the latter people. (Carreri, 'Giro del Mundo.') Among the ruins of Palenka have been found sculptured figures of serpents, which have been thought to indicate the existence of the Ophite worship in that part of the country, the seat of the Toltecans; and at the same place has been found a piece of sculpture, supposed to be a planisphere, on which are eighteen compartments representing months, which are disposed three together in the interior of a ring ornamented with hieroglyphical figures. In 1790 there was discovered, in the city of Mexico, among the foundations of the temple of Mexitili, a block of porphyry, on which are described symbolical figures, apparently constituting a planisphere or a chronological table, in which the several days of the year are distinguished by particular names and objects, and a few of them are stated to correspond nearly to the signs on the Chinese planispheres. Humboldt remarks ('Researches,' &c.) that the name of the first day is also the name of water, and that the symbol of the day consists of undulating lines resembling those which indicate Aquarius in the Greek and Egyptian zodiacs.

ZODIACAL LIGHT, a luminous appearance seen at certain times after sunrise and before sunset, from which it is inferred that there is a slight degree of nebulosity about the sun, if indeed it do not arise from the denser parts of that medium which [Comet] is more than conjectured to occupy the spaces in which the bodies of our system move.

The following description of the zodiacal light is from the pen of that careful observer, Sir John Herschel:—"The zodiacal light, as its name imports, invariably appears in the zodiac, or, to speak more precisely, in the plane of the sun's equator, which is 7 degrees inclined to the zodiac, and which plane, seen from the sun, intersects the ecliptic in longitude 78° and 258°, or so much in advance of the equinoctial points. In consequence it is seen to the best advantage at, or a little after, the equinoxes, after sunset at the spring, and before sunrise at the autumnal equinox, not only because the direction of its apparent axis lies at those times more nearly perpendicular to the horizon, but also because at those epochs we are approaching the situation when it is seen most completely in section.

"At the vernal equinox the appearance of the zodiacal light is that of a pretty broad pyramidal, or rather lenticular, body of light, which begins to be visible as soon as the twilight decays. It is very bright at its lower or broader part near the horizon, and (if there be broken clouds about) often appears like the glow of a distant conflagration, or of the rising moon, only less red. At higher altitudes its light fades gradually, and is seldom traceable much beyond the Pleiades, which it usually, however, attains and involves; and its axis at the vernal equinox is always inclined (to the northward of the equator) at an angle of between 60° and 70° to the horizon; and it is most luminous at its base, resting on the horizon, where also it is broadest, occupying, in fact, an angular breadth of somewhere about 10° or 12° in ordinary clear weather."

ZONE (the Greek ζώνη, "a belt"), a portion of a sphere intercepted between two parallel planes. When, on the globe of the earth, one plane is the equator, and four others are drawn parallel to the equator, two of which contain the circles in which the sun is vertical at the summer and winter solstices, and the two others, the circles of which are as far distant (on the earth) from the poles as the former are from the equator [Arctic Circle], the earth is divided into six zones (the polar segments being called by that name as well as the others). Of these the portions which contain the two poles are called the north and south *frigid zones:* throughout these zones the sun never rises during a part of the winter, and never sets during a part of the summer. The parts intercepted between the arctic circle and the summer solstice parallel, and between the antarctic circle and the winter solstice parallel, are called the northern and southern *temperate* zones: in every part of these there is always rising and setting of the sun for every day in the year; but in no part of them is the sun ever vertical. The parts between the summer solstice parallel and the equator, and between the winter solstice parallel and the equator, are called the northern and southern *torrid* zones: in these there is always night and day, and at every point the noon-day sun is vertical twice in the year.

The torrid and frigid zones deserve their names; but the temperate zones partake of both excessive heat and cold in those parts which are near the boundaries of the torrid and frigid zones. Every zone, in fact, partakes of all the qualities of the adjacent zones in those parts which are near the boundary. Thus near the arctic circle there are places where the shortest day is only ten minutes, and the shortest night no longer; near the solstice parallels there are places at which a part of the sun's body may be vertical, though the centre of the sun can never be so; all being within the temperate zone.

ZYMOME. A name sometimes applied to vegetable fibrin. [Fibrin; *Vegetable Fibrin.*]

SUPPLEMENT.

BANKRUPTCY. Since the article BANKRUPTCY in the first volume of this Cyclopædia was written, the law relating to bankruptcy and insolvency has undergone such extension and alteration by the legislature during the last session of parliament (24 & 25 Vict., c. 134) that a short review thereof is necessary.

The Court of Bankruptcy will henceforth consist of the present Commissioners in Bankruptcy, and to them is confided all needful powers of the Superior Courts of Law and Equity and of the Court for Relief of Insolvent Debtors. The county court judges are henceforth to exercise in the country all the powers of the present district commissioners, and vacancies in the country district commissionerships will not henceforth be filled up; and the London commissioners are, as vacancies occur, to be reduced to three. The Court for Relief of Insolvent Debtors is abolished, and the jurisdiction of the County Courts in insolvency is discontinued. The present Court of Appeal in Chancery is preserved, and appeals lie to it from the County Courts in bankruptcy as well as from the Court of Bankruptcy proper.

Questions of fact may, under the directions of the Court of Appeal, be tried in bankruptcy by juries, or issues may be sent to be tried at law. Sworn shorthand writers may be appointed; and these will certainly form a novel feature in our administration of justice.

The principal feature of the recent act is that non-traders are brought within the privileges and liabilities of bankruptcy, although the distinction between a trader and a non-trader is still for some purposes preserved. This distinction will appear from the following summary of the alterations introduced as to acts of bankruptcy.

Acts of Bankruptcy by traders are continued as hitherto, subject to such additions and alterations as are here noticed. Any person whether a trader or non-trader, may be adjudged a bankrupt for lying in prison for debt or after a detainer for debt, or in the case of a trader for *fourteen days*, instead of twenty-one days as heretofore, and in the case of a non-trader for *two months*, unless he is prepared with sufficient security for the debts in respect of which he is so imprisoned or detained; or for escaping from prison where detained for debt,

A Trader Debtor whose goods are seized and sold under judgment for a debt or money demand exceeding 50*l.*, is held to have committed an act of bankruptcy at the time of the seizure; notwithstanding which the sheriff may, unless a petition for adjudication intervene, proceed to sell the goods seized; but he must retain the proceeds for seven days, after which period he may pay them over to the execution creditor, who, however, has to pay them back, subject to deduction of the costs of action and execution, to the assignees in bankruptcy if the execution trader debtor is adjudicated a bankrupt within fourteen days from the day of sale. A *non-trader* may be made bankrupt by departing or remaining out of this realm with intent to defeat or delay his creditors, or by making some fraudulent gift or conveyance of any of his property, or by filing in court a declaration of insolvency followed, within two months, by a petition for adjudication of bankruptcy.

Acts of Bankruptcy after Judgment Debtor Summons.—Every judgment creditor for a debt of 50*l.* or upwards, may sue out against his debtor at the end of *one week* from the date of the judgment, if he be a *trader*, or at the end of *one calendar month* if he be a *non-trader*, a judgment debtor summons requiring him to appear and be examined touching his ability to pay the debt. In the same way disobedience to a peremptory order in equity, in bankruptcy, or lunacy, directing payment of money on a day certain may be followed by a similar judgment debtor summons after the expiration, in the case of a *trader*, of *seven days*, or in the case of a *non-trader* of *two calendar months*, from the day fixed for payment. Trader debtor summonses should be served personally, except in the case of persons in custody when service may be made on the sheriff, or other person in whose custody the debtor is. Where personal service cannot be effected, and the debtor is keeping out of the way, the summons may be advertised as directed by the act. The procedure upon the return of the summons is particularly provided, and the court may, upon non-payment of the debt, and whether the debtor appears or not, adjudge him a bankrupt without any petition for adjudication; but a debtor thus adjudicated upon in his absence may, within seven days from receiving notice of the adjudication, appear and show cause against it.

Proceedings to obtain Adjudication.—A debtor may himself petition for adjudication without filing any previous declaration of insolvency; but he must file a statement upon oath of his debts and liabilities, and of the causes of his embarrassments. In the case of *non-traders*, in order to support a petition for adjudication, or a judgment summons, the debt must have accrued after the 6th day of August, 1861 (the date of the passing of this act). Debtors in prison may petition in *formâ pauperis*, upon making affidavit of poverty. Jailers are to make monthly returns of all their prisoners detained for debt; and a registrar of the court for the district is monthly to visit all jails within the jurisdiction of his court, and to examine touching their estate and dealings all such prisoners included in such return who have been in custody *fourteen days* in the case of *traders*, or *two calendar months* in the case of *non-traders*. Prisoners not submitting to such examination may be committed to jail for a month, with hard labour, and also be adjudicated bankrupts. But prisoners detained solely under County Court or Small Debt warrants are not within these latter provisions, nor are they entitled to petition in *formâ pauperis*.

Procedure after Adjudication.—The official assignee must forthwith take possession of the bankrupt's estate, and must hold it until the appointment of a creditors' assignee. The first meeting of creditors and the president thereof are to be appointed by the court; and the majority in number and value of the creditors may transfer the proceedings to any County Court out of the metropolitan district; and a majority in value may then determine upon any allowance to be made the bankrupt up to the time of his passing his last examination. The proceedings in bankruptcy may be superseded, and an arrangement for winding up and administering the estate out of bankruptcy may be come to by due majorities of the creditors; and the debtor may then, upon making a full discovery, be entitled to an order of discharge. Some important provisions are made as to sale of real estate belonging to bankrupts, and particularly as to the settled real estate of non-traders; but these are of too technical a nature for discussion here.

Creditors' Assignee.—The majority in value of creditors who have proved may choose their assignee, in whom, upon confirmation and certificate by the court, the estate and effects of the bankrupt are to be exclusively vested; and the official assignee is thereupon forthwith to render to such creditors' assignee a full account of the bankrupt's estate, and of all dealings therewith, which account is to be formally audited and furnished to every creditor who has proved. The creditors' assignee may be required to give security; and he may be removed by the court at the instance of the creditors, and a new assignee may be chosen. The duties of the creditors' assignee are similar to those hitherto discharged by the official assignee; but to the latter is still entrusted the collection of all debts under 10*l.* The creditors' assignee must, from three months to three months, account to the official assignee for his dealings with the estate; and his accounts are to be printed and furnished to the creditors.

Dealings with the Estate.—Assignees may occupy leasehold premises of a bankrupt up to some day on which rent is payable not beyond six months from the adjudication, and may then elect to decline any lease or agreement for a lease under which the premises had been held. Creditors' meetings may authorise the mortgage or pledge of the bankrupt's estate.

Proof of Debts.—Creditors may prove their debts by forwarding through the General Post to the assignee a statement thereof, verified by their own declaration of its truth. False proofs entail the punishment of perjury. Landlords may prove for rent *pro ratâ* in respect of current periods. Unliquidated damages may be ascertained by the verdict of a jury before, or under the direction of, the court. Contingent liabilities may be determined and valued by the court at the instance of the person claiming the benefit of such liability.

Orders of Discharge.—The classification of certificates is abolished. Where a bankrupt is charged with any misdemeanour under this act, he may be tried by the court, or, if the bankrupt require it, by a jury either in the Court of Bankruptcy, or, in the option of that court, in *any* "of the ordinary courts of criminal justice." If the bankrupt be convicted of such misdemeanour, his discharge may be refused, or suspended, absolutely or conditionally. If he be not convicted of any such misdemeanour, his conduct is still to be inquired into by the court, and his order of discharge may be granted, or refused, or suspended, either absolutely or conditionally; and the bankrupt may be

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